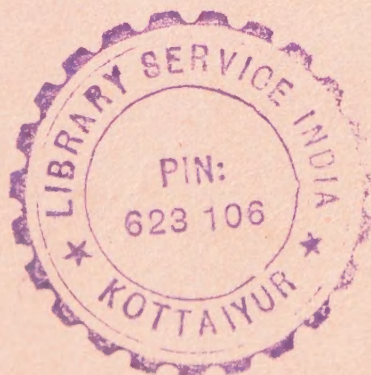


ELEMENTARY

PHYSIOLOGY



ELEMENTARY PHYSIOLOGY

No. 4722

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ARTIST

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removed, underlying it everywhere, are seen numerous fleshy bands known as **muscles**. In some places they are

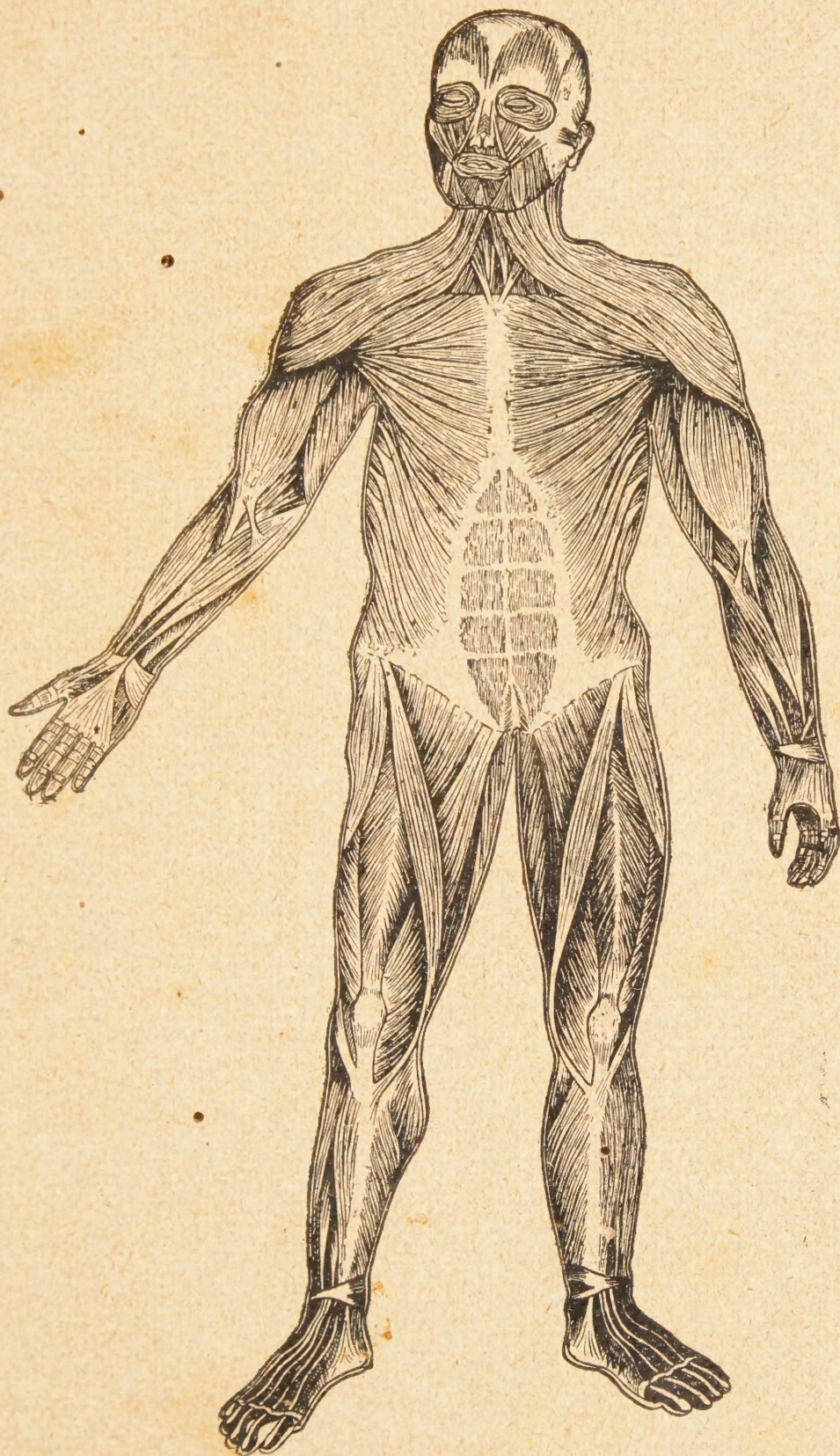


Fig. 1.—The Superficial Muscles of the Body, viewed from before.
(From Furneaux's 'Human Physiology.' By permission.)

thick and fleshy as in the calf, while elsewhere they are

spread out in thin sheets as in the wall of the belly. The muscles are attached either directly to the bones or indirectly by means of strong white fibrous bands called **tendons**. Every muscle has the power of contraction and thus becoming shorter and thicker. As the ends are fixed to bones one bone is brought closer to another, and a movement of a limb or some other portion of the body is produced. The muscles also give a graceful form to the body.

There are two kinds of muscles, viz., **voluntary** or those which are under the control of the will and **involuntary** or those which are not. The muscles of the limbs, trunk and the face (all seen in Fig. 1) are examples of voluntary muscles and muscles in the wall of the stomach, intestines or the heart are of the involuntary kind.

The Skeleton or the Bony System.—If the muscles and other soft parts are completely removed from a limb, the bones are exposed. These form the supporting frame-work of the body. The bones of the head form a strong case or brain-box, inside which the brain lies thoroughly protected. The bones of the face afford protection to the eye-balls and the organ of smell, and the jaw bones contain the teeth. In the middle line behind, running down the neck, back and the region of the loins is the so-called ‘back bone’ or the **vertebral column** which consists of a large number of separate bones or *vertebræ* placed one above the other in a column. This is the central pillar to which all other parts of the skeleton are directly or indirectly connected. The **ribs** are connected behind with the *vertebræ* of the back, and extending round the chest, are for the most part connected with the breast-bone in front. A bony cage is thus formed which contains and protects the heart and the lungs. At the upper part of the chest are the **collar bones** and the **shoulder blades**, the latter giving attachment to the bones of the arms. The lower portion of the vertebral column gives attachment to the **hip-bones**, and thus forms a hollow basin-like cavity, which supports the organs of the abdomen. Each hip-bone gives attachment to the bones of the leg.

Down the vertebral column runs a tubular cavity, which is continuous above with the cavity of the brain case. Through this passes a thick cord-like prolongation of the

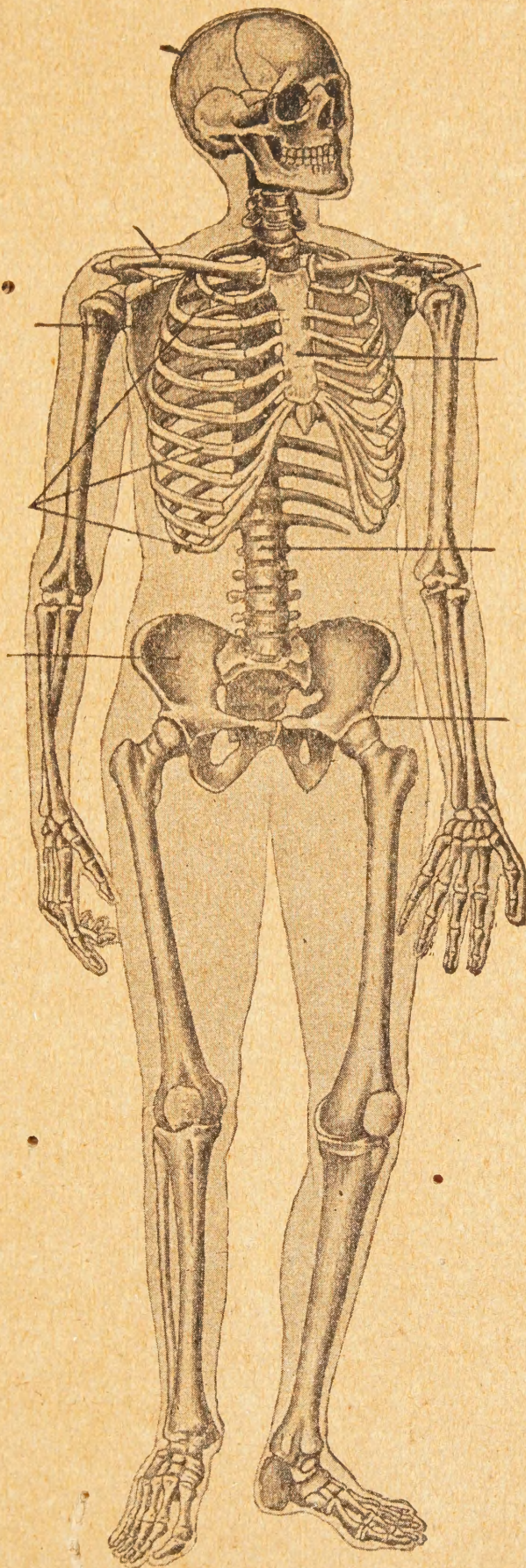


Fig. 2.—The Human Skeleton.

(From Cathcart's 'First Book of Physiology and Hygiene.'
Macmillan & Co., Ltd. By permission.)

brain known as the spinal cord. The human body is thus said to enclose two distinct tubes or cavities, one the dorsal

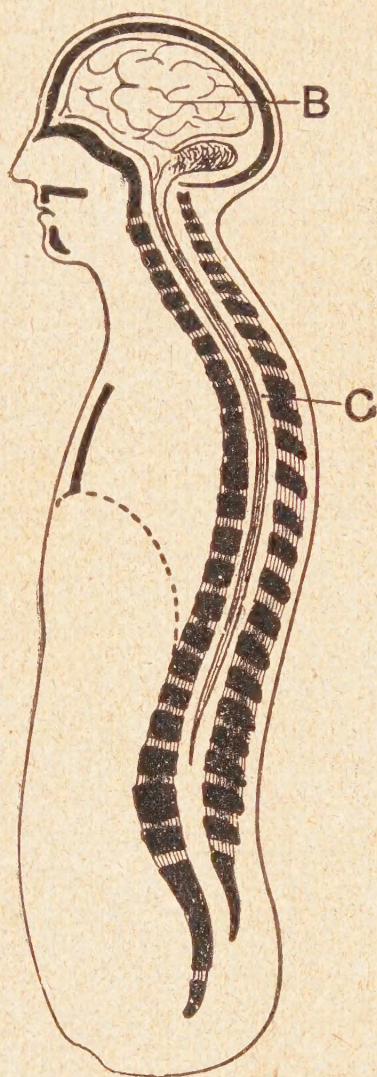


Fig. 3.—Diagram of the Body to show its Two Great Tubes.

(From Thornton's 'Elementary Practical Physiology.' By permission.)

B, brain and C, spinal cord in the dorsal tube. The wide ventral tube lies in front, and is divided into two by the dotted line that represents the diaphragm.

(Lat. *dorsum*, back) surrounded by the skull and the arches of the vertebræ and containing the brain and the spinal cord, and the other the large ventral (Lat. *venter*, belly) cavity of the trunk, which contains all other internal organs.

The Digestive System.—This consists of a very long tube known as the **alimentary canal** (Lat. *alimentum*, nourishment), opening to the outside by the mouth above and by the anus at the lower end. Behind the throat the tube passes as the **gullet**, down the neck and the thorax, and on entering the abdomen becomes dilated into a pouch-like organ, the **stomach** in which the food remains for some time while a digestive fluid acts upon it. After leaving the stomach, the food passes through a long length of the tube which is coiled on itself and known as the **intestines**, the first twenty feet or so being known as the **small intestine** and the remaining six feet, because of the wider diameter of the tube, as the **large intestine**.

The digestive fluids are poured into the alimentary canal from neighbouring glands and from the walls of the tube itself, while the food is passing through its various regions. The liver and the pancreas (or sweat-bread) are the two most important glands of the digestive system. The object of digestion is so to change the food as to convert

it into a fluid state in which it might be capable of entering and becoming a part of the blood. After all the

nutriment has been extracted from the food, the residue or fæces is passed out of the body through the anus.

The absorptive system consists of minute tubes or lymphatic

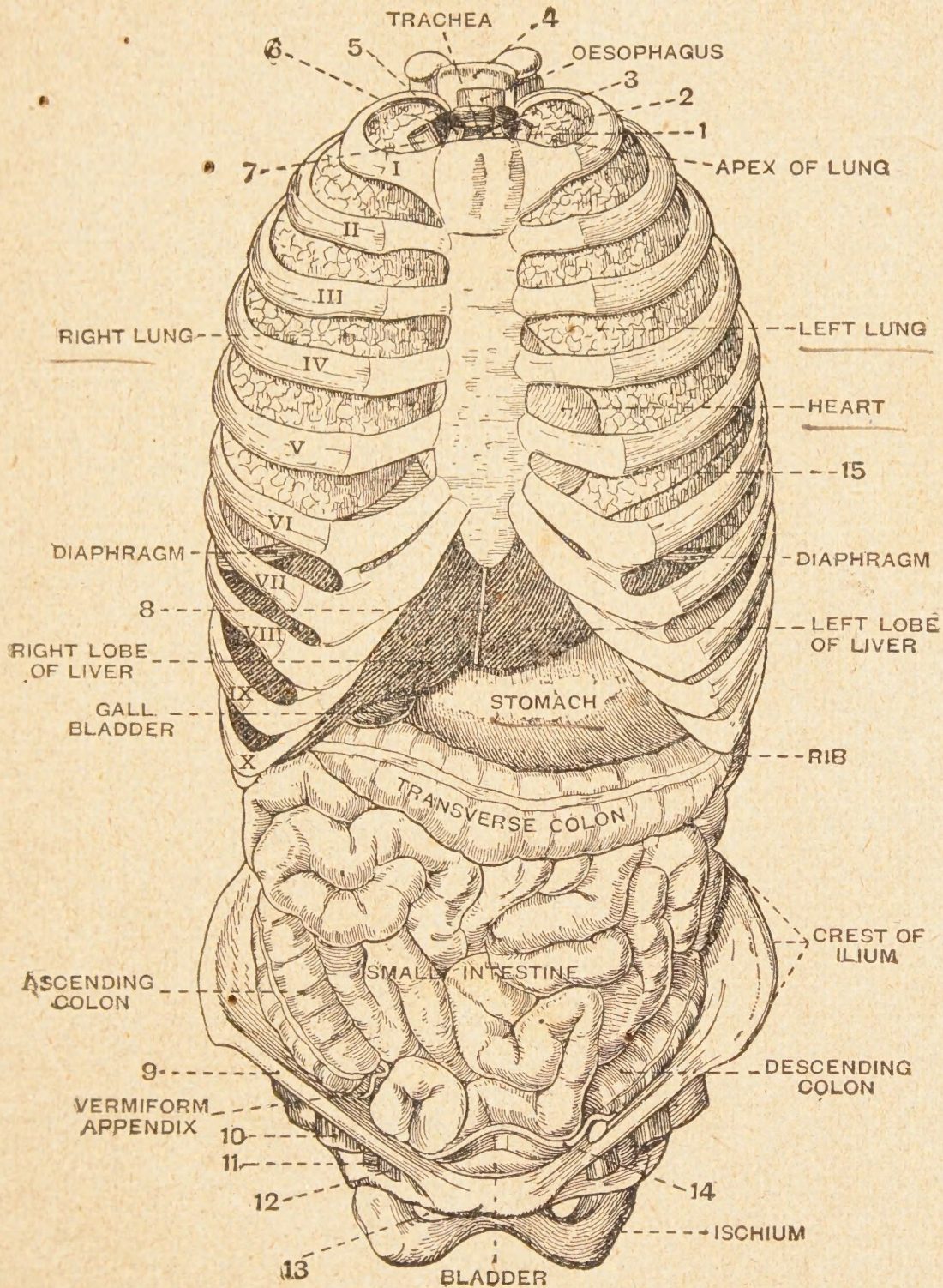


Fig. 4.—The Viscera of Thorax and Abdomen, seen from the front.

(From Thornton's 'Elementary Practical Physiology.' By permission.)

vessels which collect the nutritious material from the alimentary canal and other parts of the body and convey it to the system of blood-vessels.

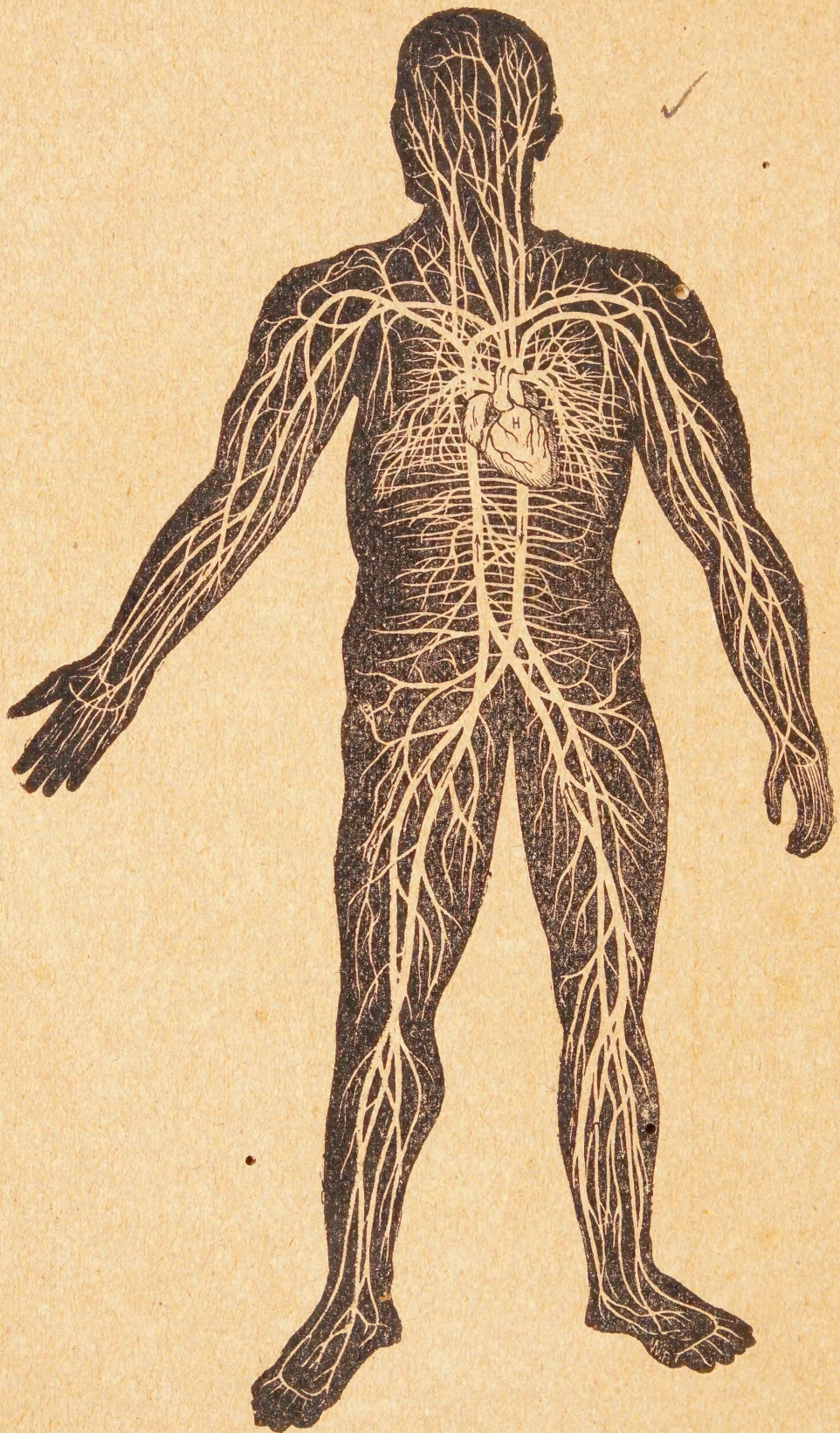


Fig. 5.—The Circulatory System, showing the Heart and the larger Blood-vessels.

(From Furneaux's 'Human Physiology.' By permission.)

H, the heart. The arrows indicate the direction of the blood-stream.

The Circulatory System.—This system consists of the **heart** and **blood-vessels** and is concerned with carrying the blood to all parts of the body and bringing it back. The blood is the medium which keeps circulating or moving round within a system of closed tubes. It is from the blood that the nourishing substances pass out to the various tissues and the waste products of their activity are thrown into the blood. The **heart** is a hollow muscular organ which, by its contractions, pumps the blood into vessels which repeatedly divide into smaller and smaller vessels, carrying the blood to every part of the body. These vessels carrying the blood from the heart are called **arteries**. In the substance of every organ, the smallest arteries break into a very fine net work of exceedingly fine blood-vessels called **capillaries**, which can only be seen with the help of a microscope. The capillaries unite to form **veins** which carry the blood back to the heart. On their course the veins join one another, until finally a few large veins pour their blood into the heart.

The respiratory system concerns itself with purifying the blood so far as its gaseous contents are concerned. All parts of the body need oxygen for their activity. The energy for work is the result of a process of oxidation of the tissues. The blood carries oxygen to the tissues, and while it is passing through the capillaries in any part of the body, oxygen passes out through their thin walls and carbon dioxide (popularly known as carbonic acid gas) passes into the blood. The blood laden with carbon dioxide returns through veins to the right side of the heart, and is sent out to the lungs to be purified.

The respiratory system consists of two **lungs** and the **windpipe** which connects them with the outside air. In the chest the windpipe divides into two branches. Each enters a lung and breaks up into a large number of smaller tubes, each of which enlarges into a tiny thin-walled **air-sac**. By the alternate expansion and contraction of the chest, air is taken in and passed out of the lungs. The impure blood circulating in the capillaries of the lungs takes up oxygen and gives out carbon dioxide. The blood is thus oxygenated and the air, now with less oxygen and more carbon dioxide than before, is thrown out of the body. This constant change of air in the lungs is known as **respiration** or breathing.

The Excretory System.—Besides carbon dioxide, the tissues discharge into the blood other more complex nitrogen containing waste products also. When the blood in the course of its circulation, goes to the **kidneys**, the latter remove these waste products from the blood, and wash them out into the bladder in the form of a watery fluid called the urine.

The Nervous System.—The brain, spinal cord and nerves, distributed to all parts of the body constitute the nervous system (Fig. 7). By

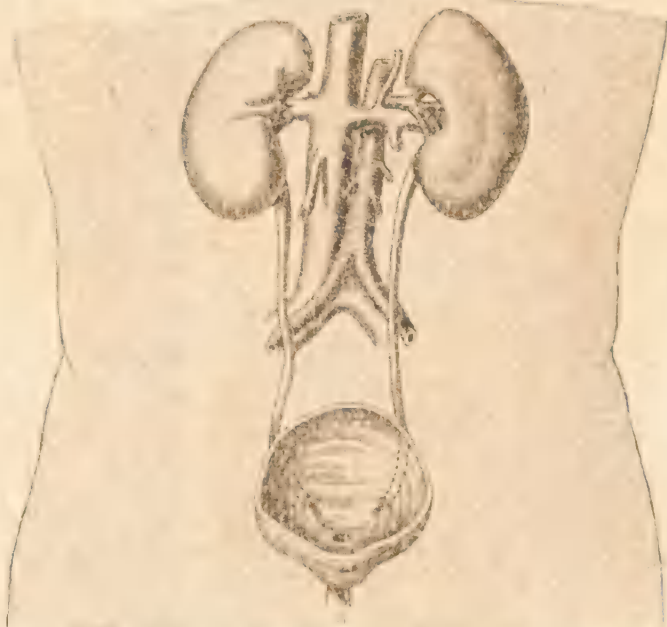


Fig. 6.—The Kidneys, Ureters and the Bladder.
(From Cathcart's *'First Book of Physiology and Hygiene.'* Macmillan & Co., Ltd.
By permission.)

The ureters are the tubes which bring urine from the kidneys to the bladder. The bladder is shown cut open to show the interior.

orders issued by the latter to the various muscles and glands to do their work as desired.

The Reproductive System.—Certain organs are set apart in the body for the reproduction of the species. Every animal and plant produces other beings similar to its own self. It is outside the scope of this book to treat of those organs, but when you grow older and are about to marry you should certainly read some good book on matters relating to sex and the responsibilities of becoming fathers and mothers. The organs differ in the male and female, and by the union of a minute microscopical cell from the male

means of these organs impressions are received from the outside world, and the working of all parts of the body is controlled and regulated. The eyes, ears, nose, tongue and skin are all connected by means of nerves with the brain where all the information is brought from the outside. The nerves may be compared to telegraph wires which are carrying messages from the various parts of the body to the brain and

with a cell from the female reproductive organ, the egg cell is formed which develops into a new individual.



Fig. 7.—General view of the Nervous System.

(From Thornton's 'Elementary Practical Physiology,' By permission.)

a, cerebrum in two hemispheres; b, cerebellum; c, spinal cord with nerves passing to all parts.

Thus 'each little child that comes into this world begins as a seed in the body of its mother and gets its life from her.'

CHAPTER II

THE COMPOSITION OF THE BODY

Tissues.—In the last chapter we have seen in a general way the organs which go to form the body. An examination of any organ shows that it is formed of one or more different kinds of materials or fabrics called tissues. Thus the brain and the nerves are formed of a soft greyish-white material called the **nervous tissue**. The red flesh is composed of **muscular tissue**, bones are formed of a hard compact substance, the **bony tissue** and so on. When the skin is being removed, it will be found to be connected with the flesh underneath by means of a soft stringy substance known as **connective tissue**. This form of tissue is found to be very widely distributed in the body, ensheathing every bone and every muscle, and binding together the different materials which go to form an organ. Bone and cartilage also are special varieties of connective tissue. Lastly **epithelial tissue** is found covering the external surface of the body, and lining the entire length of the alimentary canal, and other tubular cavities and various glands and ducts in the body. In fact, wherever there is need for a smooth continuous membrane, epithelial tissue is found to occur.

The Body as a Community of Cells.—When any tissue is examined with the aid of a microscope, it is found to be built up of a large number of similar units of living substance called **cells**, together with more or less binding material originally derived from them. Just as bricks are units of structure in building a house, so also are cells the units of living substance which form a body. The body of every one of the higher animals and plants consists of myriads of such tiny units. Just as in an organized society or civilized community there is a division of labour, various groups of people following different occupations, such as agriculturists, blacksmiths, shoemakers, weavers, etc., so also in the body different kinds or groups of cells are set apart for the performance of different functions, and have come to vary in form according to the particular kind of work they perform. Every living being is developed from a single cell, the germ or egg cell, which is formed by the union of a male cell with a female cell.

This cell goes on dividing repeatedly, and as the mass of cells grows, groups of cells become arranged together to form special tissues and organs. While doing so, they assume their characteristic shape and become fitted for their special work. Every tissue thus differs from another in the form and nature of its cells, and the way in which these cells are united together by intercellular substance. It would be interesting to consider what these different types of cells look like when seen under a microscope and the nature of the duties they perform. It must be remembered that a microscope provided with an ordinary high power objective magnifies an object four or five hundred times, that is to say makes a pin's head appear to be the size of a cart-wheel.

The Nerve Cells.—These cells are found in the brain and the spinal cord and are very varied in shape. Each cell has a central mass, containing a denser body in the middle which is known as the **nucleus**, and several processes which branch and interlace with the branches of neighbouring cells. One of these processes is very much drawn out and covered with sheaths of other materials, thus forming a nerve-fibre. A nerve, as seen in a dissection, is a bundle composed of innumerable nerve-fibres.



Fig. 8.—Nerve Cells.

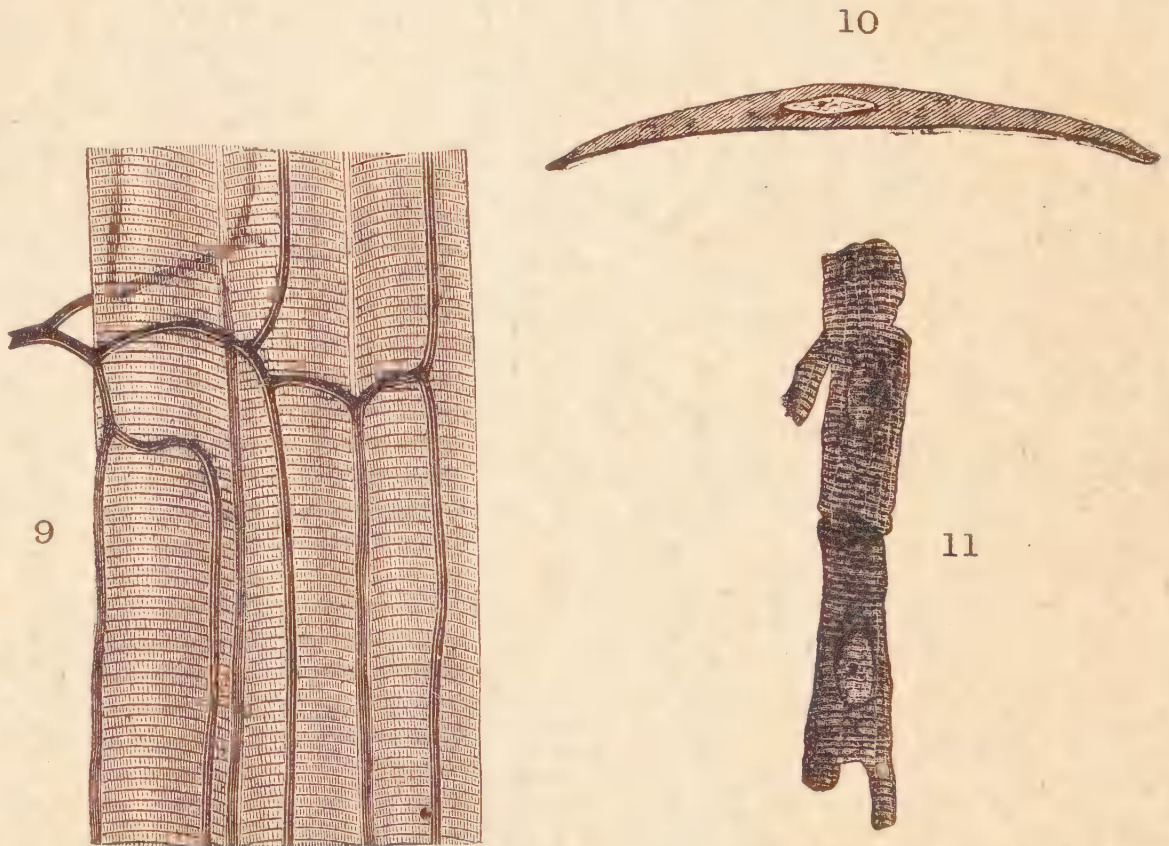
(From Quain's '*Anatomy*.' By permission.)

One process is covered with sheaths to form a nerve-fibre.

These cells with the fibres form the great telegraph system of the body. They are constantly carrying

messages with great speed and the messages leap across from branches of one cell to those of a neighbouring one. Reports from all parts of the body are received by them. These cells are engaged in thinking and issuing commands and all the highest faculties of understanding and reasoning are due to their proper working.

The Muscle Cells.—These are the labourers in the body. Each cell knows only how to do one thing, namely, to contract. It becomes shorter and thicker, with the result that a muscle composed of thousands of cells becomes shorter and thicker, by all of them contracting together. Movements of different parts of the body are thus brought about.



Figs. 9, 10 and 11.—**Muscle Cells.**

(From Quain's 'Anatomy' and Thornton's 'Elementary Practical Physiology.' By permission.)

Fig. 9, striped or voluntary muscle fibres; Fig. 10, unstriated or involuntary muscle fibre; Fig. 11, muscle fibres from the heart.

The muscle cells forming the muscles of the limbs and other parts of the body which are under the control of the will, obey the commands received from the nerve cells. These muscle cells are so long and drawn out as to be usually referred to as **muscle fibres** and are marked across

or **striped** (Fig. 9). The unstriped muscle fibres are shorter and taper at both ends (Fig. 10). They are arranged so as to form thin sheets in the wall of the alimentary canal, and by their contraction squeeze and push the food along and finally eject the fæces. They also occur in the wall of the urinary bladder. Lastly the muscle cells composing the heart, though not working under the control of the will, are striped (Fig. 11) but they are very much shorter than ordinary striped muscle fibres.

The Connective Tissue Cells.—These cells are generally irregular in form and situated wide apart from one another, there being more intercellular substance in this kind of tissue than in any other.

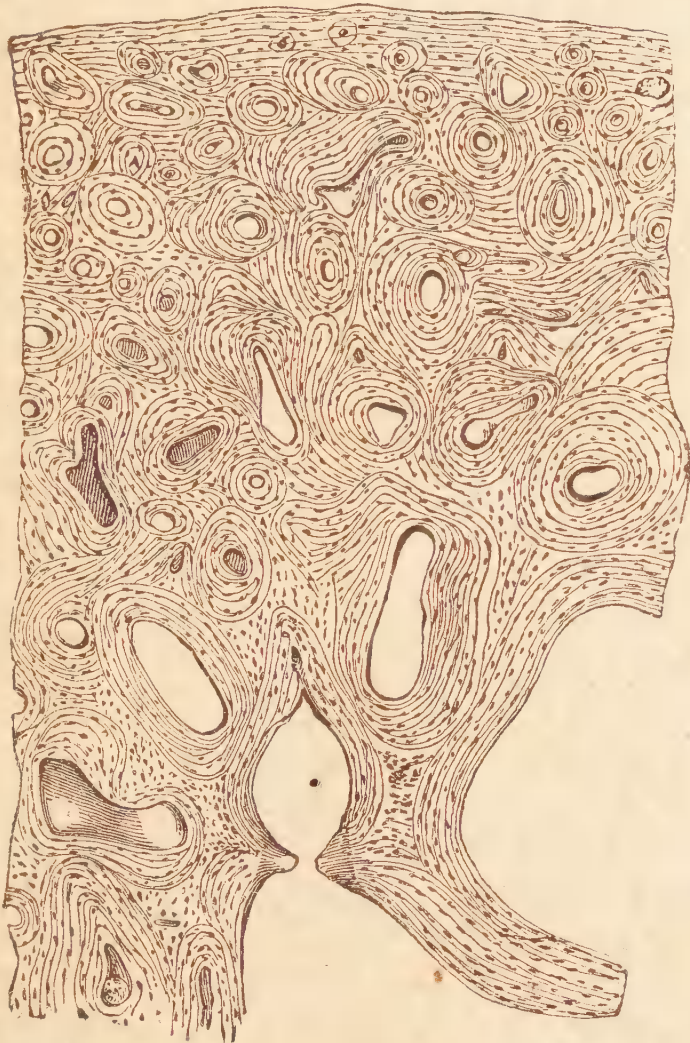


Fig. 12.—Section of Bone.

(From Quain's 'Anatomy.' By permission.)

Fig. 12, bone cells are arranged in rings round the canals which contain the blood-vessels.

As an example a thin section of bone may be examined. The **bone cells** are tiny and of an irregular shape and are



Fig. 13.—A Bone Cell, very highly magnified.

arranged in concentric rings round small canals which contain the blood-vessels. Bone also is a living tissue and the cells are nourished by the fluid oozing through the thin walls of the blood-vessels. It is characteristic however of these cells, that they surround themselves with walls of lime, and thus build up the supporting framework of the body.

Another important group of workers in the body are the **blood-cells** (Fig. 45). They do not combine to form a tissue, but float in a colourless liquid. The blood keeps flowing through various tubes in the body, known as arteries, capillaries and veins. The blood-cells are of two kinds, red and white. The red cells are little rounded discs of a pale yellow colour, but on account of their vast numbers they make the blood appear of a beautiful red colour. They carry oxygen gas to all other cells in the body, without which the other cells could not live. The white cells are of an irregular shape and very much fewer in number. Each of these resembles a minute creature consisting of no more than a single cell called an amœba, which is found in pond water. Under the microscope the

organism is seen to be constantly altering its form. As that organism engulfs its food, so these white cells in our body are seen to devour disease germs or other foreign particles which may gain their entry into the blood.



Fig. 14.—Two Epithelial Cells from the inside of the Mouth.

(From Quain's 'Anatomy.'
By permission.)

Magnified 260 diameters.

Epithelial Cells.—These are found covering the surface of the body and lining the entire length of the alimentary canal. The cast off layers of the skin of a frog may be examined under the microscope to get a good idea of these cells, or numbers of them can be removed easily from your mouth-cavity by passing the tip of your finger across the inside of your cheek.

Each cell is a tiny mass of living substance, and contains a denser central body known as the **nucleus**.

In certain situations in the body another kind of epithelial cells manufacture lubricating or digestive fluids. Such cells are known as the **gland cells** and in some places they are aggregated to form fairly big organs called the glands. Different glands manufacture different kinds of secretions which are in many cases carried away from the gland by special ducts or tubes to the required place.

Chemical Composition of the Body.—We have seen that the body is built up of organs, these of tissues, and tissues of cells. But from the point of view of the chemist, the whole body is composed of various chemical substances. The living material of which the bodies of all animals and plants are composed is known as *protoplasm*. This is a very complex substance, the composition of which keeps constantly changing, and is different in different parts of the body. Generally speaking, the following chemical elements are found in the body:—Oxygen, nitrogen, hydrogen, carbon, calcium, phosphorus, sulphur, chlorine, fluorine, potassium, sodium, magnesium, and iron. The proportions in which these elements occur in the body are graphically represented in the accompanying diagram.

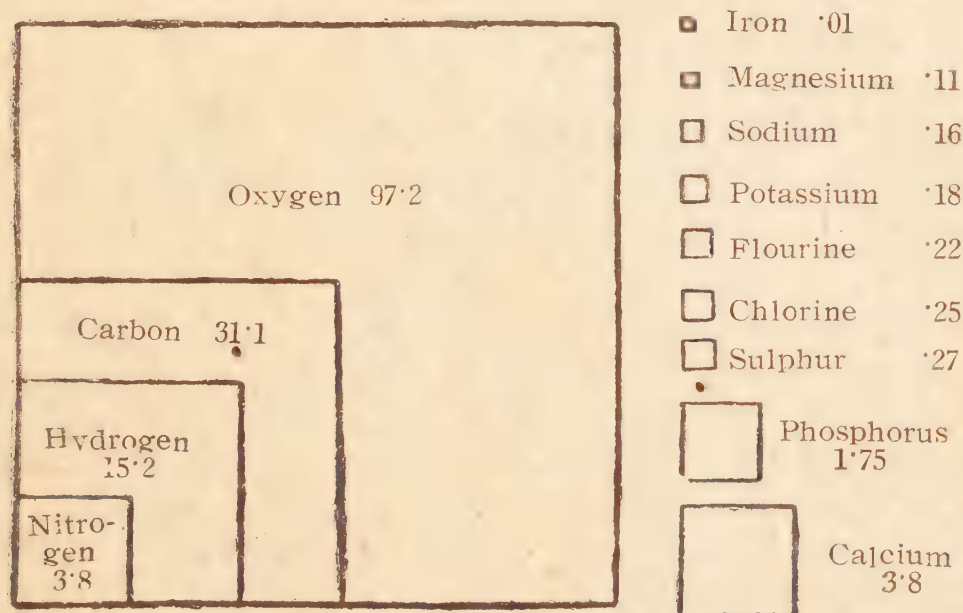


Fig. 15.—Elements composing a Human Body weighing 154 pounds.

(From 'Biology for Beginners' by Truman J. Moon :
Harrao & Co. By permission.)

Figures express pounds.

Some of these elements are solids, others gases, and students should learn something about them from an

elementary book on chemistry. In the body they are found to occur in the form of various compounds, except the first three which occur in the gaseous state also.

Chemical Compounds of the Body.—In the body the elements are found combined together to form various compounds. Thus carbon dioxide is a gas formed by the union of oxygen with carbon, water is a compound of hydrogen and oxygen. Sodium chloride is a compound of the metal sodium with a gas called chlorine. Hydrochloric acid is a compound of hydrogen and chlorine and occurs in minute quantity in the digestive juice secreted by the stomach. Calcium carbonate is composed of calcium, carbon and oxygen and calcium phosphate is a compound of calcium, phosphorous and oxygen. These are both found in bones. All these compounds are known as **inorganic compounds**, as they are not confined to the bodies of plants and animals but are found in nature also. Besides these they are more complex compounds which always contain carbon as one essential ingredient, and are confined to the bodies of the plants and animals. These are called **organic compounds**. They are originally built up or manufactured by the plants from simple inorganic substances found in the soil and the air. Plants differ from animals in being able to depend entirely on their own resources, using for their food simple inorganic substances only and combining them with the help of energy derived from the sun, into organic compounds. Animals also take in water and some mineral-salts, but they could not live on these alone. They depend for their life on the organic compounds made by plants. Flesh eating animals live on other animals, which in turn use plant food. It must be remembered that plants form these organic compounds for their own growth and store away some in their roots, stems or leaves for future needs, or in their seeds as a provision for the next generation.

There are three great classes of organic compounds, namely, **Proteins**, **Carbohydrates**, and **Fats**. They are found in different forms in the bodies of all plants and animals. Of these, **proteins** alone contain nitrogen in addition to carbon, hydrogen and oxygen, and consequently the body can be built from them alone. As examples of proteins may be mentioned glutenin found in wheat and other

grains, legumin in peas, beans and lentils, albumen in the white of egg, casein in milk and myosin in meat. **Carbohydrates** are composed of carbon, hydrogen and oxygen, with always twice as much hydrogen as oxygen and varying amounts of carbon. Common examples of carbohydrates are various kinds of starch and sugar. Starch is found abundantly in wheat or maize flour, rice grains and potatoes, and different kinds of sugar in sugar-cane, beet-root and various fruits, etc. Carbohydrates are found almost entirely in plants, whose tissues are largely composed of them. When animals eat them, they are mostly oxidized to produce heat and energy. A small reserve of carbohydrate is always retained in our body as glycogen (a kind of starch found in the liver) and a sugar called grape-sugar circulates in the blood and is found in other tissues, to be used by them as fuel. Any excess of carbohydrates over the requirements of the body is converted into fat and stored as a reserve of fuel. Lastly, **fats** are also composed of carbon, hydrogen and oxygen. They differ from carbohydrates in having less oxygen. Hence they oxidize more readily and so their chief use is to produce energy. Plants store fats or oils mostly in their seeds to supply energy for growth, and animals also store fats in various places in their body for various purposes. As examples of oils may be mentioned mustard oil, cocoanut oil, almond oil, and of fats, butter contained in milk, and fat in between and surrounding the flesh of the animals.

It is obvious that substances of which our bodies are made, are the substances which are supplied in the foods we take. We shall consider these classes of compounds again in greater detail in the chapter dealing with foods.

What is going on in the Body? We eat food which always consists of five classes of compounds, viz., proteins, carbohydrates, fats, water, and mineral salts. These are variously changed during the processes of digestion and ultimately enter the blood stream in a suitable form. They are then carried to all parts of the body and enter into the composition of the cells and tissues of the body. The body thus grows. At the same time oxygen from the air is also taken in by the lungs and carried to all parts by

the blood. By combining with various compounds composing the cells of the body, it serves to break them up into simpler substances. One result of this process of oxidation or slow burning is that heat or energy necessary for all work is generated, but at the same time all parts of the body are being constantly broken down or undergoing waste. It must be clearly recognized that all work whether physical or mental is at the expense of the breaking down of the body. Processes going on inside the body such as circulation of blood, respiration, etc., also require a certain amount of energy and involve a breaking down of the tissues. The simpler compounds that result from the process of breaking down, such as water, carbon dioxide, urea, etc., are to a great extent removed from the body, and it wastes and loses weight in showing life and activity. But the living body has the power of making good the loss by taking in food, and the tissues are able to repair or renew themselves. If the body is able to assimilate more than it loses, the net result is growth and increase in weight. The process of oxidation that goes on in the body may be compared to the burning or combustion of wood or charcoal that goes on after the fire is once kindled. The products of combustion if collected are found to be the same, viz., carbon dioxide and water and the incombustible portion of the food remains as mineral ash. Ordinary burning or combustion is rapid oxidation accompanied by light and heat, but the process in the body is a slow one and although heat is produced, there is no flame.

Body and a Steam-engine compared.—The human body is often compared to a steam engine. Both need a supply of food (fuel) and both require oxygen to unite with the food and set free its energy. In both, heat is the result of oxidation. In the engine this heat produces steam, the force of which is utilized to move the wheels. In the body the energy set free manifests itself in muscular movements and other kinds of work. In both, waste products result from the process and these have to be removed. In the body some parts of the food taken are left unused, in the engine fire ashes are left behind. The comparison ends here. An engine or any other machine cannot obtain its own food. It does not assimilate or grow. It cannot repair itself.

It requires an outside being to start, direct and control it. It cannot reproduce its kind. A living organism only can feed, grow, and reproduce. The human body is a machine, but it is a wonderful machine that has the power of growth, self-repair and reproduction. It is further capable of initiating and controlling its own working and can give a suitable response to the outside forces working on it.

CHAPTER III

THE SKELETON

THE SKULL

The Bony Skeleton.—In a previous chapter we have considered the general build of the body. We shall now devote our particular attention to the **skeleton** and the various bones of which it is formed. The skeleton contains over two hundred separate bones, united together to form various **joints**. The important functions of the skeleton are (1) to support the soft parts and thus give shape to the body, (2) to protect important organs and (3) to serve for the attachment of muscles. The bones forming the skeleton are of various kinds. Some are **flat** bones, like those of the skull, others are **long** like those of the extremities. The bones forming the wrist and the ankle are **short** bones, while those forming the vertebral column are known as **irregular** bones.

The skeleton may conveniently be divided into four parts :—

1. The Skull or the bones of the head and the face.
2. The Vertebral Column or the back-bone.
3. The bones surrounding the cavity of the thorax.
4. The bones of the upper and the lower extremities or limbs.

The Skull.—The skull consists of the bones of the head and may be divided into the Cranium or the brain-box and the bones of the face.

The **Cranium** is the large bony box which contains the brain and is composed of eight flat bones, firmly united together by the saw-like edge of one bone interlocking with the edge of another bone to form a bony union known as a **suture**. These bones are :—

One Frontal bone.	One Occipital bone.
Two Parietal bones.	One Sphenoid bone.
Two Temporal bones.	One Ethmoid bone.

The **Frontal bone** forms the forehead or the front of the cranium. It also forms the roof of the orbits, and the upper portion of the nose.

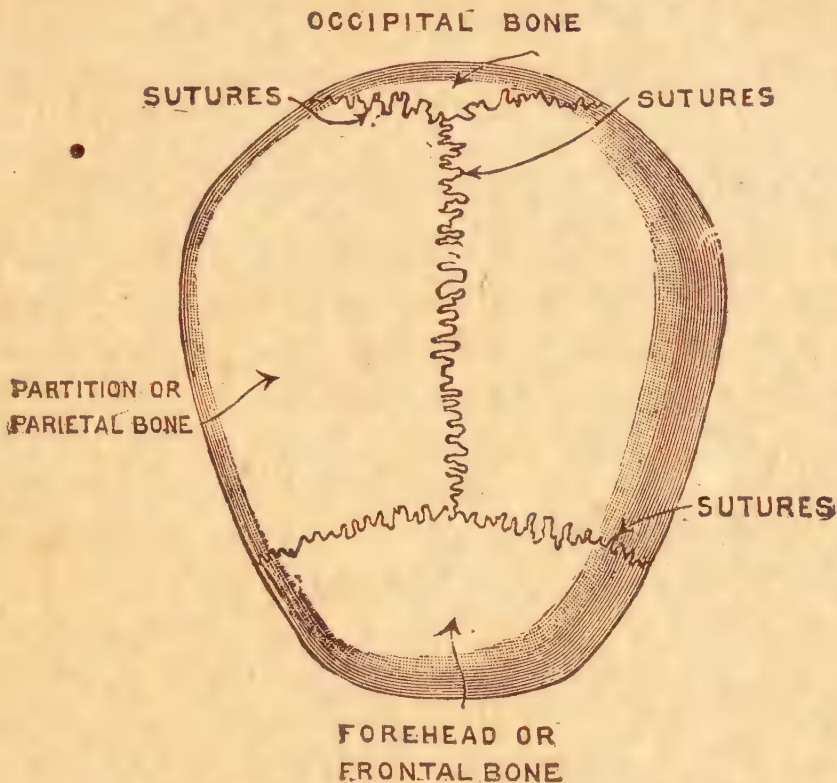


Fig. 16.—A View of the Top of the Brain-box (Skull) showing the Position of the Bones and their Sutures.

(From Barnett's 'Making of the Body.' By permission.)

The two **Parietal bones** form part of the sides and the roof, and are united to the frontal bone in front, the temporals below, and to the occipital behind.

The two **Temporal bones** form the temples and complete the side-walls of the skull. The bone on each side contains a narrow canal leading to the middle ear. Behind the opening is a marked projection, in front of which is a smooth depression into which the upper end of the lower jaw fits. The internal ear or the essential organ of hearing is contained inside the pyramidal projection on the inside of the bone.

The **Occipital bone** forms the back of the head and is united above to the two parietal bones. In its lower part the occipital contains a large hole, the **foramen magnum**, through which the brain becomes continuous with the spinal cord.

On each side of the foramen magnum are two smooth projections, the **condyles**, which move on the first vertebra, thus permitting the nodding movements of the head.

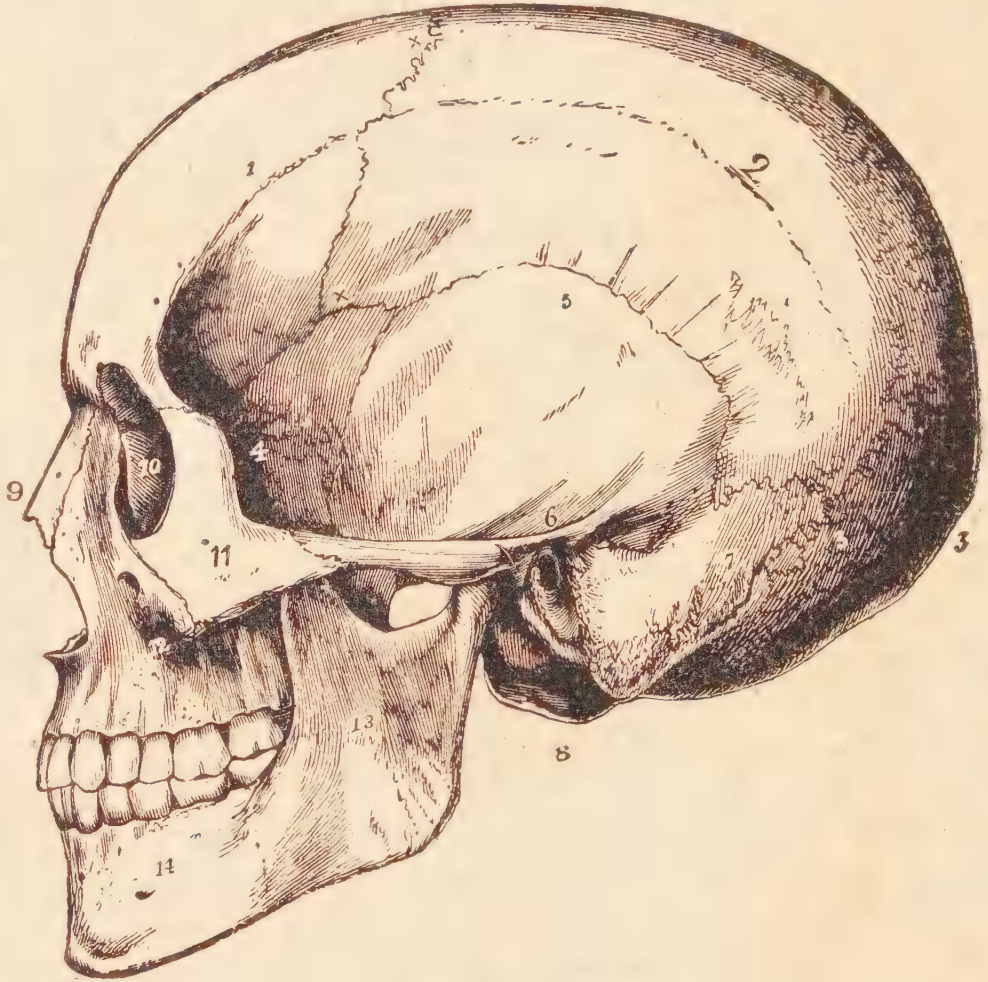


Fig. 17.—Side View of the Skull.

(From Quain's 'Anatomy.' By permission.)

1, frontal bone ; 2, parietal bone ; 3 and 8, occipital bone ; 4, wing of the sphenoid bone ; 5, 6 and 7, temporal bone ; 9 nasal ; 10, lachrymal bone, in the inner wall of the orbit ; 11, malar bone ; 12, superior maxillary ; 13 and 14, inferior maxillary.

The **Sphenoid** is a bat-shaped bone and forms a portion of the base and the sides of the skull. It unites with the occipital bone behind, the temporals on the sides and several other bones of the skull.

The **Ethmoid** is a small bone lying in front of the sphenoid forming the roof of the nose and part of the side walls of

the orbit. It is perforated like a sieve to allow the passage of small twigs of the nerves going to the nose.

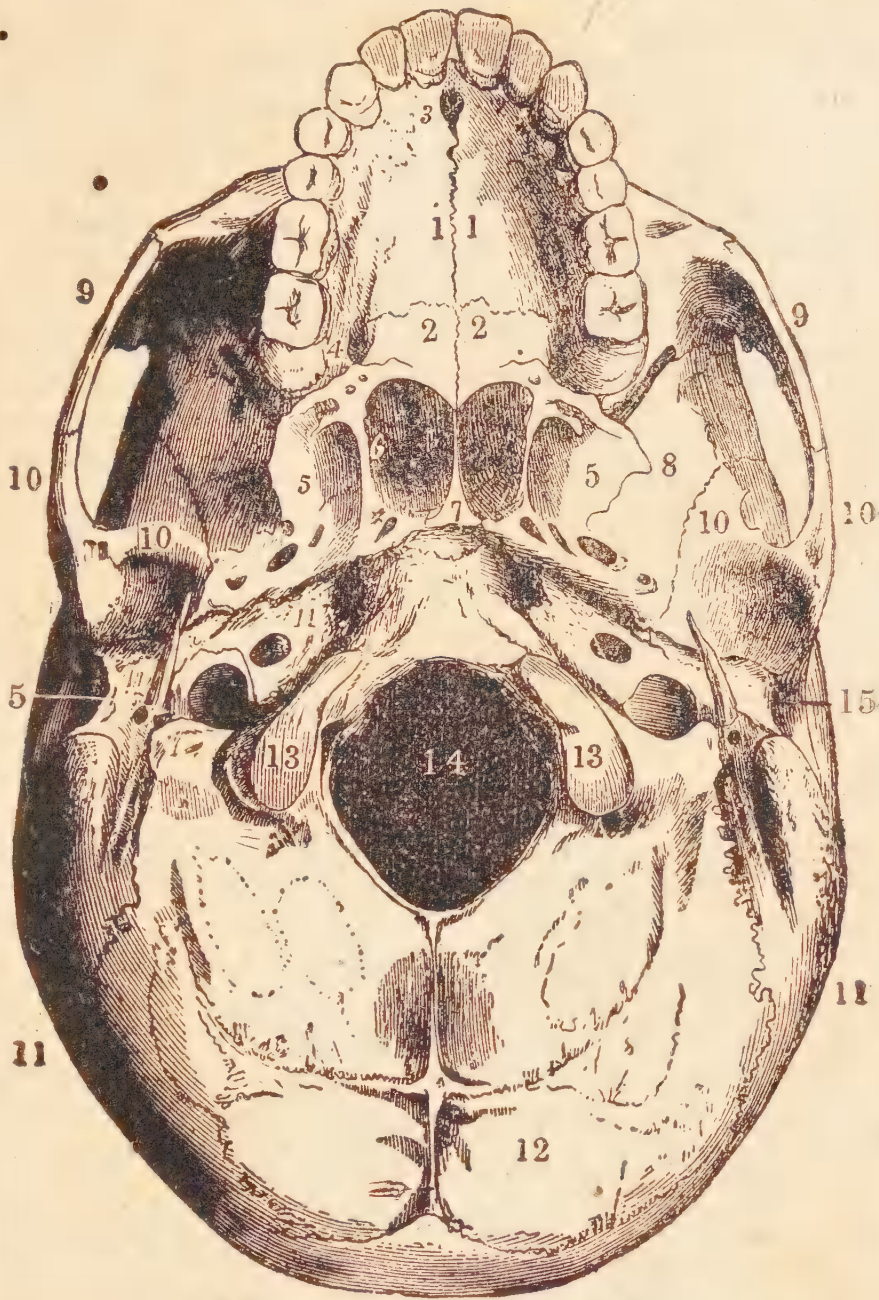


Fig. 18.—The Under-surface of the Skull.

(From Furneaux's '*Human Physiology*'—after Quain.
By permission.)

1, superior maxillary bones; 2, palate bones; 5 and 8 are on the sphenoid bone; 6, hinder opening of the right nostril; 7, vomer bone between the hinder openings of the nostrils; 9, malar or cheek-bones; 10, temporal bones; 11, lower portion of parietal bones; 12, occipital bone; 13, condyles of the occipital bone; 14, foramen magnum; 15, entrance to ear.

The **face** is formed of fourteen bones, all of which except the lower jaw, are immovably united with the cranium. These are :—

Two **Superior Maxillary** or upper jaw bones.

One **Inferior Maxillary** or lower jaw bone.

Two **Malar** or cheek-bones.

Two **Palate** bones.

Two **Nasal** bones.

Two **Spongy** bones.

Two **Lachrymal** bones.

One **Vomer** bone.

} In connection with the nose.

Two **superior maxillary bones** form the upper jaw and a portion of the roof of the mouth. On the lower border of each are eight sockets for the teeth.

The **inferior maxillary** or lower jaw bone is also known as the mandible. It forms the chin and on its upper edge has sixteen sockets for the lower set of teeth. By its hinder and upper part on each side, it articulates with the temporal bone, forming a hinge joint. It is the only bone of the face which is capable of movement and the movements are not only upwards and downwards but to a slight extent from side to side also, thus enabling the food to be masticated, the teeth in the lower jaw working against the upper set.

Two **malar** or cheek-bones, form the prominences of the cheek.

Two **palate bones** form the back part of the palate.

Two small **nasal bones** form the upper part of the bridge of the nose, the rest of the nose being formed of cartilages.

Two small **lachrymal bones**, one situated in the inner wall of each orbit, contain the passage for carrying off the tears from the eyes to the nose.

The **spongy** or twisted bones, one in each chamber of the nose. They are small scroll-like bones which are twisted about, so as to increase the extent of the membrane lining the nose.

One **vomer bone** forms the back part of the middle partition in the nose.

CHAPTER IV

THE SKELETON (*continued*)

BONES OF THE TRUNK

The Vertebral Column.—The 'back bone' or the vertebral column consists of thirty-three irregular bones superimposed one upon the other and united by strong bands of fibrous tissue.

The upper twenty-four bones, forming the neck, back and loins, are separate and slightly moveable, and the lower nine are fused together. The individual bones are known as *vertebræ* and between one vertebra and another is a pad of cartilage. The cartilages act as buffers and serve to distribute any shocks or jars, produced in jumping, etc.

The various *vertebræ* are named according to the position in which they are found. The **cervical** *vertebræ* found in the neck are seven in number. The next twelve are called the **dorsal** or thoracic *vertebræ* forming the upper part of the back. These give attachment to the twelve pairs of ribs. The remaining five moveable *vertebræ* are known as the **lumbar** *vertebræ* and form the lower part of the back. The lowest of these rests upon a large wedge-shaped bone called the **sacrum**, formed by the fusion of five sacral *vertebræ*. To the lower end of this is attached the **coccyx** or the tail bone formed of four very small *vertebræ* fused together.

On either side, the sacrum is united to two large hip bones which meet in front, forming a basin-shaped cavity called the pelvis.

All *vertebræ* except the first two are constructed on the same plan. To study this plan a typical vertebra may be taken, say from the middle of the thoracic region. It consists of the following parts :—

(1) The **body**, the solid disc forming the anterior part of the bone, to the back of which is attached, (2) the **neural arch** which encloses the spinal canal; and arising from the arch are (3) three processes or projections, two

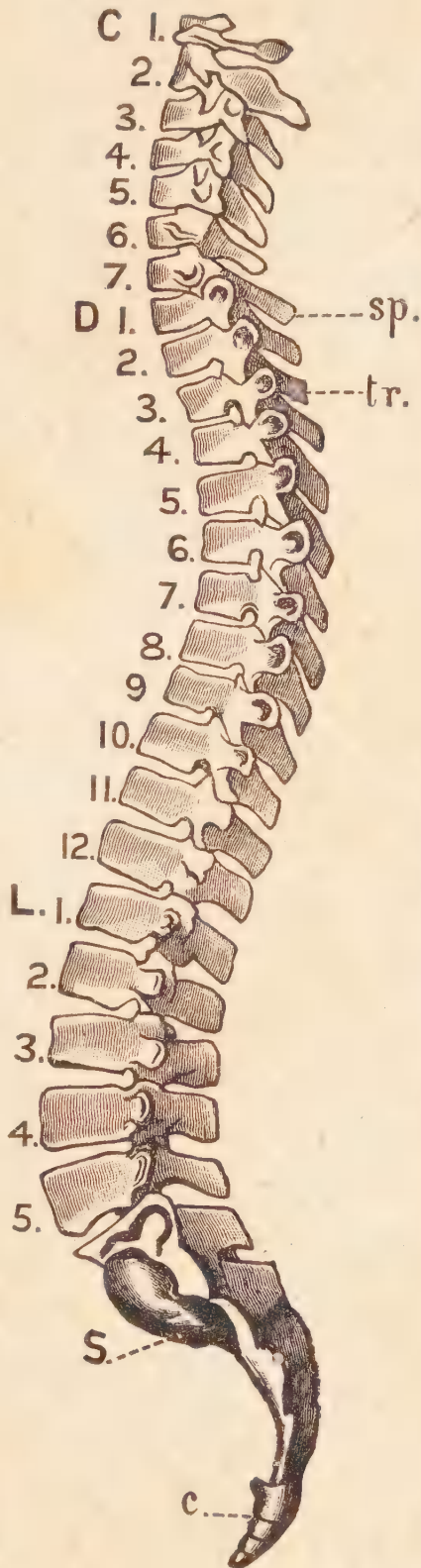


Fig. 19.—The Vertebral Column, viewed from the left side.

(From Notter and Firth's 'Practical Domestic Hygiene.' By permission.)

C1, first cervical vertebra; D1, first dorsal vertebra; L1, first lumbar vertebra; S, first sacral vertebra; C, first coccygeal vertebra.

transverse, one on each side, and one spinous pointing backwards and downwards. The spinous process can be readily felt in the back. These processes give attachment to the various ligaments which hold the bones together and to the various muscles which enable us to bend the back.

The vertebræ in the various regions have the same parts as the typical dorsal vertebra described above, but show marked distinctions peculiar to each region. The weight and size of the vertebræ increase from above downwards, so that the lumbar vertebræ are the heaviest and the largest while the cervical are light and small. The transverse processes of the cervical vertebræ are perforated, a blood vessel passing through the holes on either side. The dorsal vertebræ have long spinous processes and smooth areas on either side of the body and near the tips of their transverse processes, for the ribs to join.

The lumbar vertebræ have thick and strong transverse and spinous processes.

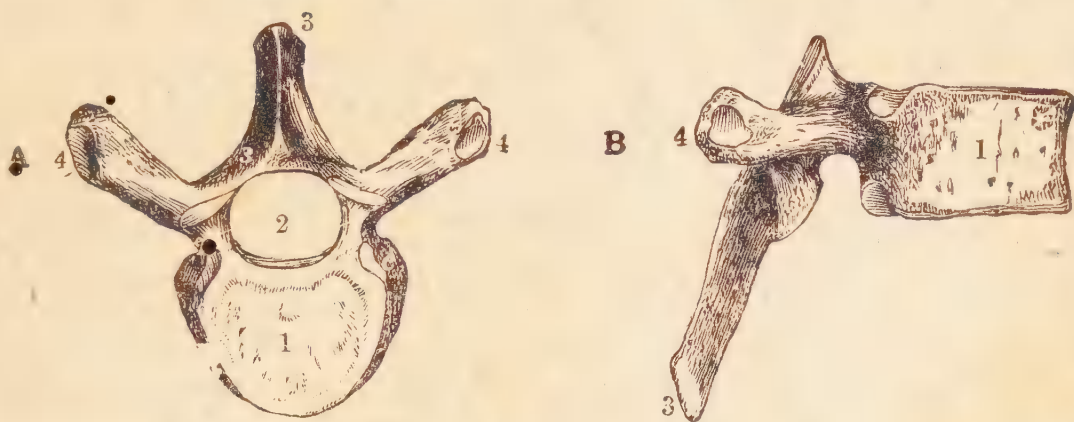


Fig. 20.—A Dorsal Vertebra. A, viewed from above; B, viewed from the right side.

(From Quain's 'Anatomy.' By permission.)

1, body; 2, spinal cavity; 3, spinous process; 4, transverse processes. Note the smooth surfaces near the tip of the lateral processes and on the sides of the body, for articulation with the ribs. These smooth surfaces are only found on the dorsal vertebræ.

We now turn our attention to the first two vertebræ which show marked peculiarities. The first cervical vertebra is called the **atlas**, as it supports the globe-like head. It is ring-like, and has practically no body, but has two smooth articular surfaces on its upper side over which the condyles of the skull can easily glide forwards and backwards. The spinous process is very rudimentary.

The second cervical vertebra is called the **axis**. It has on the upper surface of its body a peg-like process called the **odontoid process**, which fits into the ring of the atlas. It is kept in position by a transverse ligament which passes across the atlas. It will thus be seen that in turning our head from side to side, the atlas bearing the skull, rotates round the odontoid process of the axis.

When the vertebræ are arranged in a column, with the intervertebral discs between them, and the processes of the vertebræ bound together by ligaments, they form a strong flexible support. The neural arches of the vertebræ then form a long bony tube, known as the spinal canal which contains and protects the spinal cord.

The column does not form a straight pillar, but has several curves. The cervical region shows a small curve

with the convexity forwards, while the dorsal region shows a larger curve with the concavity forwards. In the lumbar region again the convexity is forwards while the sacral is concave in front.

The Thorax.—The bony thorax is a conical cage formed by the twelve thoracic vertebræ behind, twelve ribs on either side and the sternum or the breast bone in front. Only the upper ten ribs are united to the sternum by means of cartilages, the last two are not connected with the sternum and are hence called floating ribs. The function of the bony cage is to contain and protect the heart and the lungs and also to protect the liver, spleen and kidneys which though lying in the abdomen are covered by the ribs.

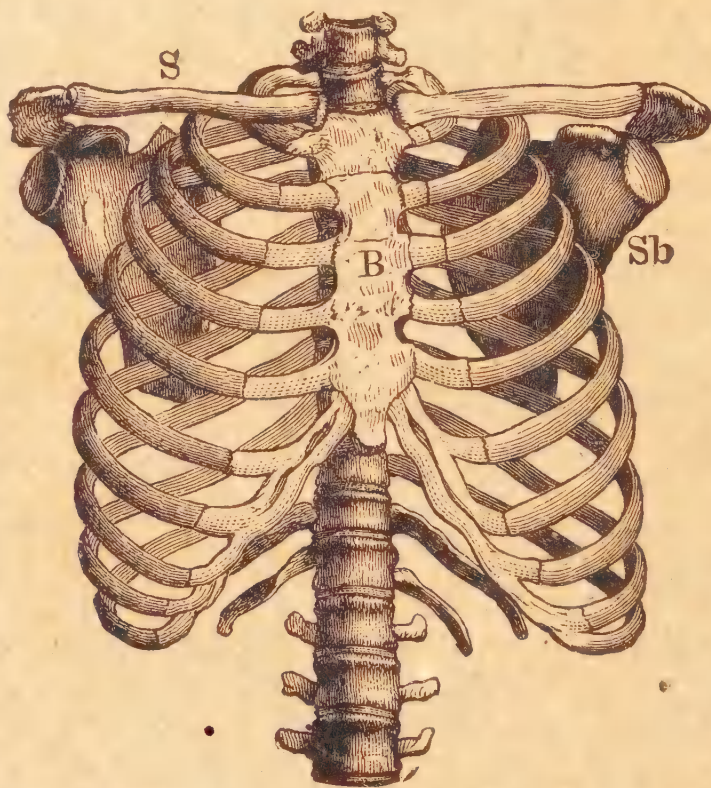


Fig. 21.—Front view of Bones of Thorax.

(From Thornton's '*Elementary Practical Physiology*.'
By permission.)

B, sternum or breast bone ; S, clavicle or collar-bone ; Sb, scapula or shoulder blade. The vertebræ and the ribs are not labelled. The cartilages connecting the ribs with the sternum are of lighter shade.

The **sternum** or the breast bone is a flat bone 6 to 7 inches long, broad at its upper end and narrowing towards the lower. It consists of three parts, the lowest of which is

formed of cartilage. To the upper part, the collar bones articulate on either side. On both sides of the sternum, the upper seven costal cartilages join the ribs with the sternum, the remaining three cartilages unite with each other and with the seventh costal cartilage.

The **ribs** are twenty-four in number, forming twelve pairs. Each pair of ribs is connected behind with a dorsal vertebra and except the last two pairs with the sternum in front. The upper seven ribs are connected with the sternum by separate pieces of cartilage called the costal cartilages, the costal cartilage of the next three pairs are connected with each other and then with the costal cartilage of the seventh rib. The eleventh and twelfth ribs are the shortest; they do not reach the sternum at all, and are hence called floating ribs. The ribs are curved bones and are not placed horizontally but incline downwards and forwards.

The spaces between the ribs are called intercostal spaces, and in life are occupied by intercostal muscles. These muscles are flat pieces attached to the edges of the ribs above and below, and by raising the ribs enlarges the chest cavity during respiration.

Through the upper opening of the thorax the windpipe, gullet and various blood-vessels and nerves coming from or going into the neck enter the thorax. The lower opening is closed in life by an arching muscle, the diaphragm, which separates the cavity of the thorax from the abdomen. Through it passes the gullet and the various blood-vessels and nerves coming from or going to the abdomen.

CHAPTER V

THE SKELETON (*continued*)

THE BONES OF THE LIMBS .

The Upper Extremity.---Each upper extremity is made up of the **shoulder**, the **upper arm**, the **forearm**, the **wrist** and the **hand**. The bones of these parts are as follows :—

The **clavicle** or collar bone, and the **scapula** or the shoulder blade, together forming the **shoulder girdle**, which serves to connect the arm with the trunk.

The **humerus** or bone of the upper arm.

The **radius** and the **ulna** in the forearm.

Eight **carpals** or wrist bones.

Five **metacarpals** or bones in the palm of the hand.

Phalanges or finger bones, three in each finger and two in the thumb.

The **clavicle** is a curved bone, which articulates with the sternum on the inner side, and with the scapula on the outer.

The **scapula** is a flat triangular bone lying on the back over the upper ribs. Its back surface is divided into two unequal portions by a transverse ridge of bone called the **spine** which expanding at its outer end into a large process articulates with the clavicle.

At the upper and outer angle of the scapula is a smooth oval depression, called the **glenoid cavity**, into which fits the rounded upper end of the humerus, to form the shoulder joint. The scapula is attached to the chest only by means of muscles and ligaments and has thus a free range of movement.

The **humerus** or upper arm bone, is a long bone, consisting of the head or the upper end, the shaft, and the lower end. It articulates above with the glenoid cavity of the scapula to form the shoulder joint, and below with the bones of the forearm to form the elbow joint.

The **radius** and the **ulna** are the two bones in the forearm. The **radius** lies on the inner or thumb side of the forearm.

Its upper end is small and rounded and the lower broad and expanded. It articulates with the humerus above and the wrist bones below. The **ulna** lies on the same side as the little finger and has a larger upper and small lower end. The upper end articulates with the humerus forming a large joint and has a projection which forms the prominence of the elbow. In the position of the arm, with the palm of the hand facing forwards and the thumb turned outwards, the radius and the ulna lie parallel to each other. In turning the hand from this position to one in which the thumb is turned inwards, the radius turns round the ulna and the two bones cross each other.

The **carpus** or wrist is made of eight small **carpal bones** arranged in two rows. Being made of small bones, held in position by ligaments, the wrist is flexible and has a great range of movement.

The **metacarpal bones** are five in number and lie beyond the carpal bones, forming the palm. They articulate with the carpal bones above and with the phalanges below.

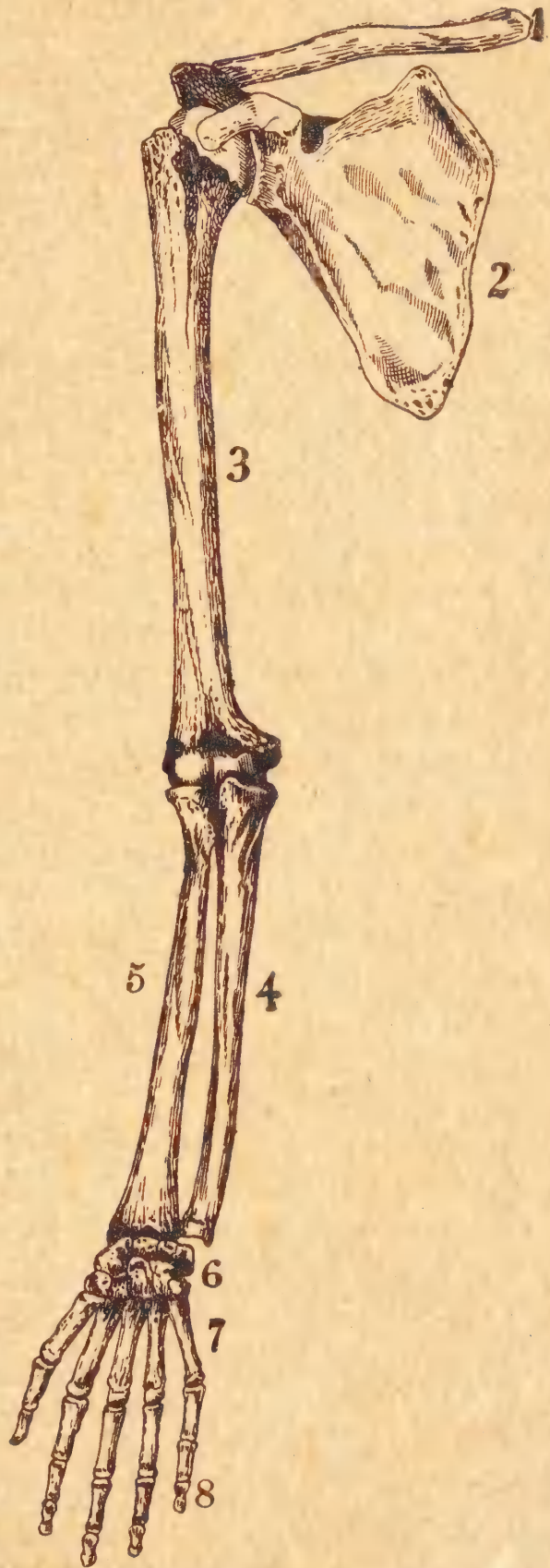


Fig. 22.—Bones of the Upper Limb.

(From Furneaux's 'Human Physiology.' By permission.)

- 1, clavicle; 2, scapula; 3, humerus; 4, ulna; 5, radius; 6, carpal bones; 7, metacarpal bones; 8, phalanges.

The **phalanges** are fourteen in number, three in each finger and two in the thumb.

The Lower Extremity.—The lower extremity is made on the same general plan as the upper extremity and has corresponding parts. Thus it consists of the hip, thigh, leg, ankle and foot. The bones of these parts are described below.

The hip bone or pelvic girdle is often called **os innominatum**

on account of its irregular shape. The two hip bones on the sides, with the sacrum in between, form a basin-shaped cavity called the **pelvis**. Each hip bone is a large irregular bone consisting of three parts which are distinct in early childhood but get firmly united later on. The broad upper portion is called the **ilium**; the thick lower portion, on which one rests in sitting is the **ischium**; and the flat front portion which unites with its fellow of the opposite side is the **pubis**. All the three bones, ilium, ischium and pubis meet at one end, to form a deep cup called the **acetabulum** which receives the rounded head of the thigh bone. The bones of the pelvis are placed like a basin supported on the



Fig. 23.—The Right Scapula from behind.

(From Furneaux's 'Human Physiology.' By permission.)

- 1, glenoid cavity; 2, the blade; 3, the spine; 4, process which articulates with the outer end of the clavicle.

two legs, and serve in their turn to support the organs lying in the abdomen.

The **femur** or thigh bone is the longest bone in the body and corresponds to the humerus in the arm. At its upper end it has a circular knob-like **head** which fits into the acetabulum to form the hip joint. The lower end is expanded and articulates with the tibia of the leg.

The **tibia** and the **fibula** are the two bones of the leg, corresponding to the radius and the ulna of the forearm.

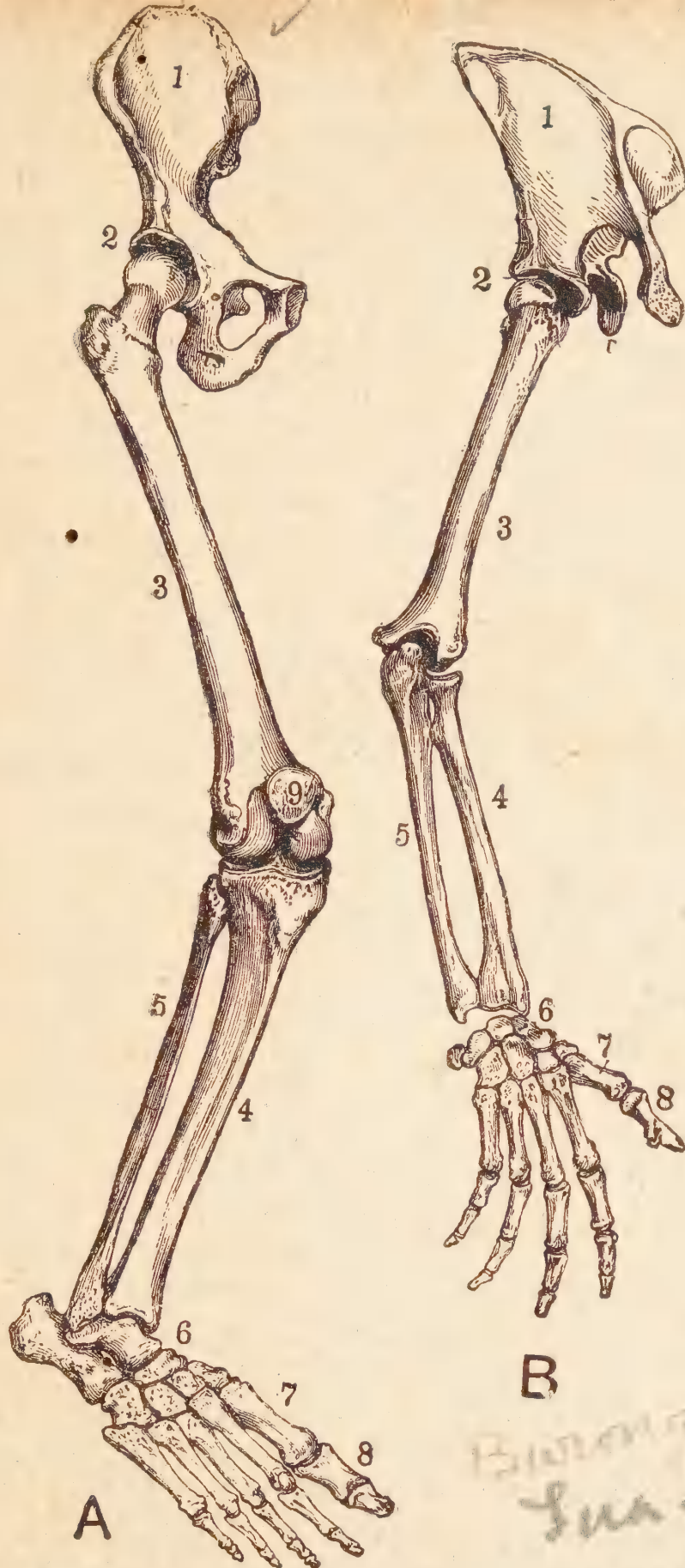


Fig. 24.—The Bones of the Upper and Lower Extremities, so placed as to show corresponding parts.

(From Furneaux's 'Human Physiology.' By permission.)

A. The Lower Limb.

1. hip bone.
2. acetabulum.
3. femur.
4. tibia } lower leg.
5. fibula }
6. tarsus or ankle—seven bones
7. metatarsus.
8. phalanges of toes.
9. patella.

B. The Upper Limb.

1. scapula.
 2. glenoid cavity.
 3. humerus.
 4. radius } forearm.
 5. ulna }
 6. carpus or wrist—eight bones.
 7. metacarpus.
 8. phalanges of fingers.
- The patella has no corresponding part in the arm.

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Handwritten text: Kakeah, Buring, Sun.

The **tibia** is the larger and the inner of the two bones and has a sharp projecting edge which is felt as the 'shin.' It is therefore popularly known as the shin bone. Its upper end is large and articulates with the femur. In front of the knee joint and connected with the tibia by a strong thick ligament, is the **patella** or knee cap. The lower end of the tibia is smaller and articulates with the ankle bones.

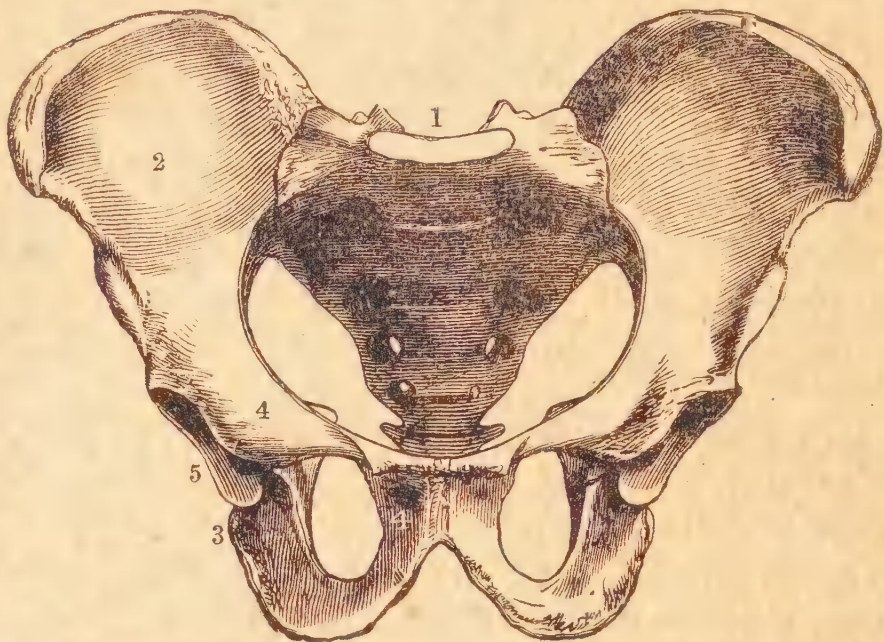


Fig. 25.—The Bony Pelvis, consisting of the Sacrum, Coccyx and the two Hip Bones.

(From Quain's 'Anatomy.' By permission.)

1, sacrum ; 2, ilium ; 3, ischium ; 4, pubis ; 5, acetabulum.

to form the inner prominence of the ankle. The **fibula** is a long thin splint-like bone placed on the outer side of the tibia. Unlike the radius and the ulna, it does not rotate round the tibia but is fixed to it at both ends. Its lower end forms the outer prominence of the ankle.

The ankle or **tarsus** corresponds to the wrist but has only seven bones. One of these is a thick bone called the **astragalus** which articulates with the tibia ; another projects backward to form the prominence of the heel and is known as the **os calcis**. Into this bone is inserted the **tendon** of **Achilles**, a large tendon coming from the calf muscles of the leg. The remaining five tarsal bones form a part of the instep.

The **meta-tarsal** bones are five in number and correspond to the metacarpal bones. To these are articulated the **phalanges**, two in the great toe, and three in each of the other toes.

CHAPTER VI

JOINTS, MUSCLES AND MOVEMENTS

Joints.—Where two bones meet, they form a joint. Joints are either movable or fixed. In fixed joints such as between the bones of the cranium, bones meet each other, but are incapable of any movement. In these the bones are interlocked by small processes from each fitting into indentations of the other thus forming what are called **sutures** (see Fig. 16).

In the **movable joints** bones are capable of movement, the extent of which varies in different cases. These are classified under four heads:—

1. **Ball and socket joints.**—In these joints, the globular head of a long bone fits into a cup-shaped hollow of another bone. As examples may be mentioned the hip and the shoulder joints. These joints are characterized by great freedom of movement.

2. **Hinge joints.**—In these, movement occurs backwards and forwards in one plane just like a door or the lid of a box moving on a hinge. Examples of this kind are at the elbow, the knee, the ankle and the joints between the phalanges of the fingers and toes.

3. **Pivot joints.**—In these joints, one bone forms a pivot or a peg, round which the other rotates; for example, the joint between the atlas and the axis vertebræ which enables the head to move from side to side.

4. **Gliding joints.**—In these joints there is a slight gliding movement of one bone over another, usually through the interposition of a pad of cartilage. Examples of such joints are the articulations of the bones of the wrist and the joints between the various vertebræ.

Ligaments.—The bones are bound together by tough, white fibrous bands called **ligaments**. They are more or less elastic and thus allow some freedom of movement to the bones. The ligaments can be observed after removing the muscles covering a joint. The muscles will be found united to bones by other white bands called **tendons**.

Cartilage.—Cartilage is a hard, but flexible substance. The external ear is a cartilage covered by thin muscles and skin. There is also cartilage forming the greater portion of the nose. There are flexible pads of cartilage between the bodies of the vertebræ, enabling us to bend the back. These pads of cartilage also serve to deaden the effect of a shock which would otherwise be felt in jumping. There are also cartilages which connect the ribs with the sternum and thus serve to form a flexible framework.

Cartilage is also found to cover the ends of long bones where they meet each other in forming a joint. Cartilaginous surfaces are smooth and the ends of bones glide over each other more easily. In the case of ball and socket joints, the lining cartilage serves to deepen the cup which is better able to hold the rounded end of the bone which fits into it.

Formation of a Movable Joint.—In order that movement in a joint may take place smoothly and without friction, the ends of the bones forming a joint are covered with a layer of smooth cartilage. To further reduce friction to a minimum, the joints are lined by a delicate membrane which secretes an oily substance which serves to lubricate it. To keep the bones in position the joint is covered by a loose bag of fibrous tissue called the capsule of the joint, which is strengthened on the outside by muscles.

As an example of a typical movable joint the parts entering into the formation of the hip joint may be studied. Here the ball-like head of the femur fits into the cup-shaped acetabulum of the hip bone. The head of the femur is covered by cartilage and the cup is lined by a rim of cartilage. A round ligament passes from the head of the femur to the bottom of the cup inside the joint. The capsular ligament surrounds the joint. This is lined by a synovial membrane which secretes the lubricating fluid. The capsule is surrounded by muscles. The thigh can be bent or flexed at the hip by the muscles passing in front and straightened again by large muscles attached behind to the hip bone.

Muscles.—We have learnt in the first chapter that the flesh covering the different parts of the body is composed of a large number of distinct bands or **muscles** and that the various movements are produced by the contraction of

these muscles. The muscles of the limbs, trunk and face are under the control of the will and are described as **voluntary** while those composing the wall of the stomach, intestines and the heart are not so controlled and are known as **involuntary**.

The voluntary muscles are of various shapes. Those of the limbs are usually thicker in the middle than at the ends,

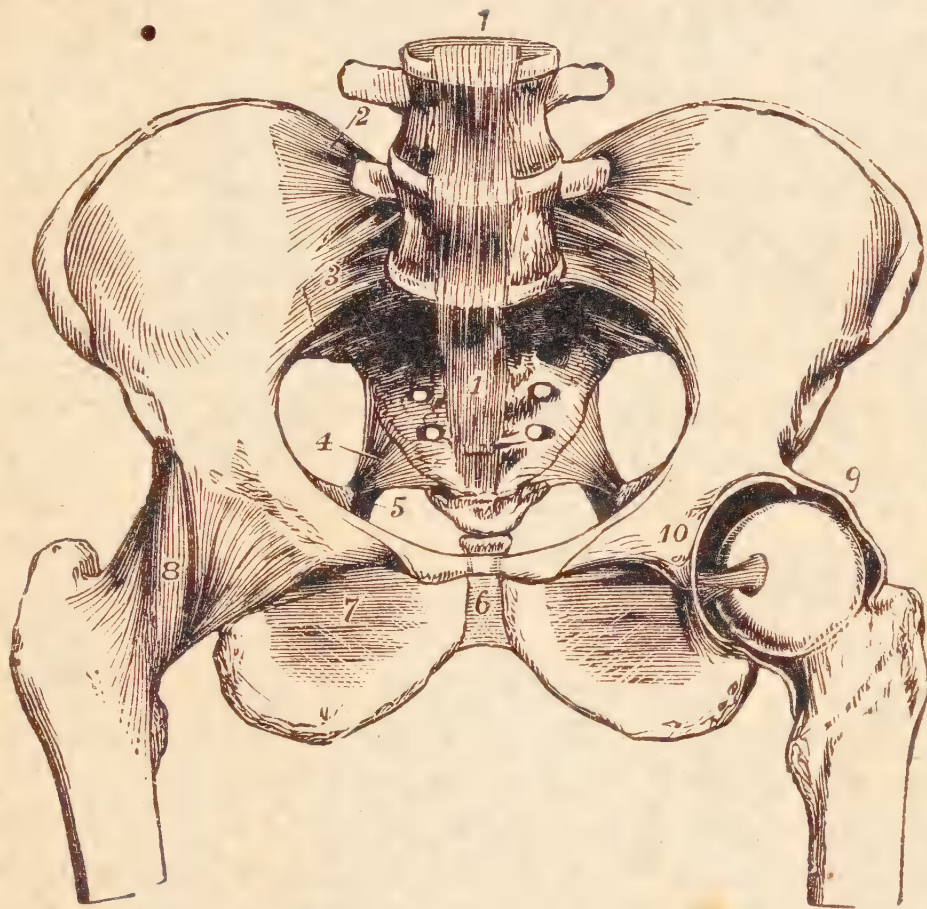


Fig. 26.—Articulations of Pelvis and the ball and socket joint of the hip.

(From Quain's 'Anatomy.' By permission.)

1, ligament passing from vertebræ to sacrum ; 2, 3, 4, 5, 6 and 7, other ligaments ; 8, capsular ligament of hip joint on the right side, on left side the capsular ligament has been removed and femur turned outward to show the synovial cavity and round ligament ; 9 and 10, cut edge of capsular ligament,

where they are often continued into **tendons**, which serve to connect them to the bones. Some muscles may be directly fixed to the membrane covering a bone. A muscle may have more than one tendon at one of its ends. One end of a muscle is fixed to one bone, and the other end to another, the muscle thus passing over a joint. When the muscle contracts one bone is brought nearer to the other. Thus

the biceps muscle raises the fore arm, bringing it closer to the upper arm. As it contracts the muscle becomes shorter and thicker. The relatively fixed point is known as the **origin** of the muscle, while the point of attachment to the more movable part is known as the **insertion** of the muscle. Thus the biceps muscle has its origin on the scapula by two heads or tendons (Lat. *bi*, two ; *caput*, head) and is inserted on the radius.

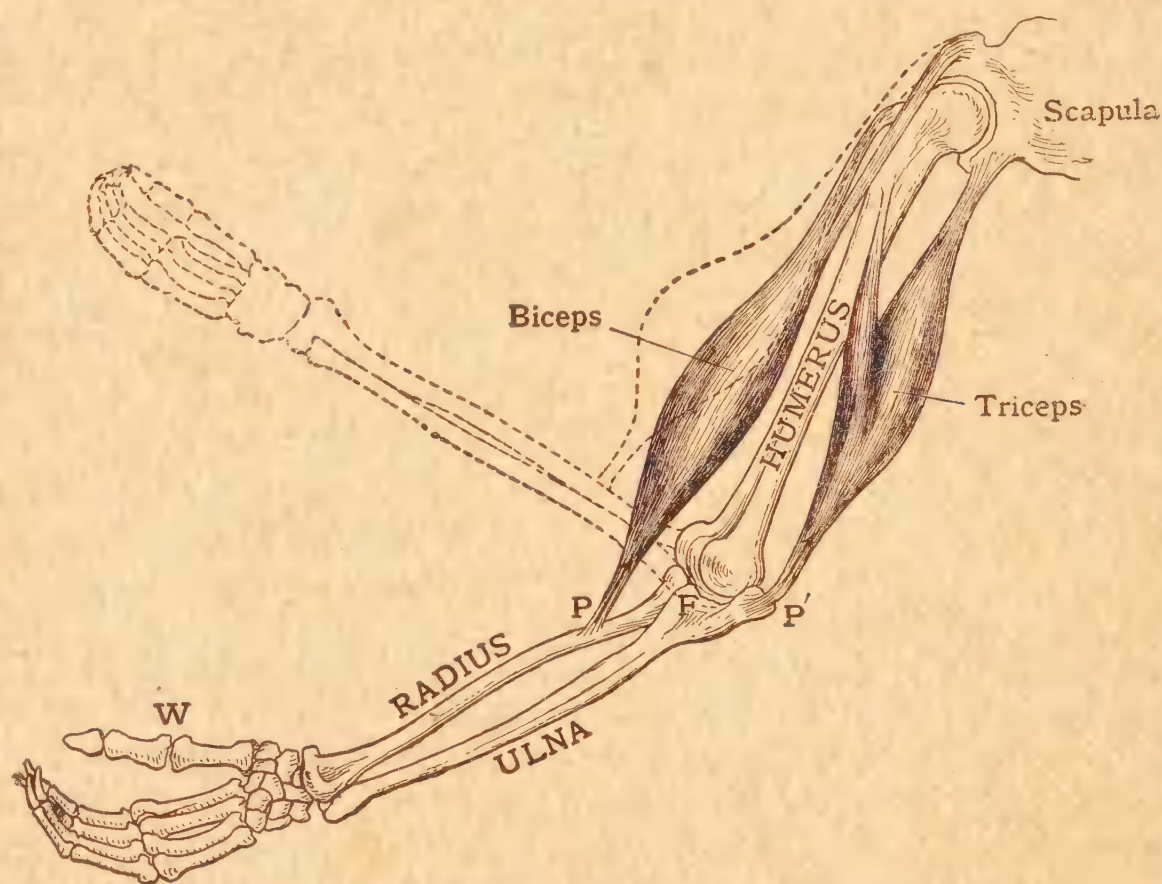


Fig. 27.—The action of the biceps and triceps muscles.

(From Thornton's 'Elementary Practical Physiology.'
By permission.)

The biceps bends the arm at the elbow-joint, and the triceps straightens or extends it. P and P', insertion of muscles where the power acts ; F, fulcrum ; W, weight or resistance.

In other cases the muscles are in the form of thin broad sheets, such as the muscles forming the front and side walls of the abdomen and the diaphragm. The abdominal muscles by their contraction compress the abdominal cavity and the arching diaphragm becomes flatter during its contraction and thus increases the cavity of the thorax during inspiration.

The Bony Levers.—The muscles in producing motions of different kinds use the bones as levers. The term **lever** is taken from the science of mechanics and means a rigid bar or rod which moves about a certain fixed point called the **fulcrum**. You may have seen a man trying to raise a heavy stone with a crowbar. He places one end of the bar under the stone and presses down the other end. Here the bar is the lever and the ground under the bar serves as the fulcrum. The force which the man applies is called the **power** and the stone is the **weight**. Levers are divided into three orders, according as the fulcrum, the weight or the power is in the middle.

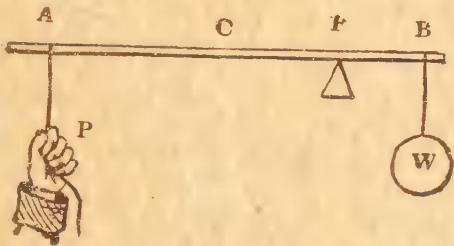


Fig. 28.—Lever of first order.
(From Tate's 'Mechanism.'
By permission.)
Fulcrum in the middle.

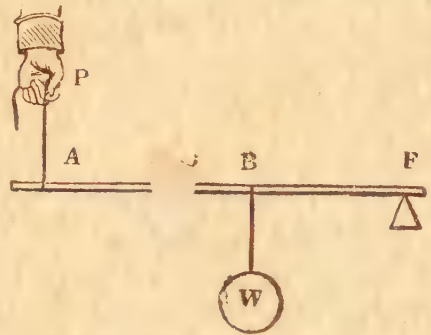


Fig. 29.—Lever of second order.
(From Tate's 'Mechanism.'
By permission.)
Weight in the middle.

In the case of movements in the body, the fulcrum is the joint about which the movement takes place; the power is applied at the point of insertion of the muscle which causes the movement, and the weight is the resistance offered by the bone that is raised.

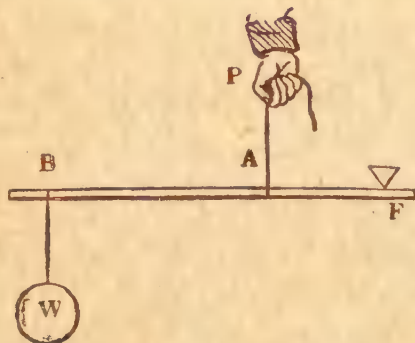


Fig. 30.—Lever of the third order.
(From Tate's 'Mechanism.' By permission.)
Power in the middle.

Two kinds of levers are illustrated in the bending or flexion and straightening or extension of the fore arm illustrated in Fig. 27. In both these cases the fulcrum is at the elbow joint. The bending is brought about by the biceps acting at its insertion on the radius. Here the radius serves as a lever of the third order, as the fulcrum is at the elbow joint, the power is applied at the insertion of the biceps on the radius and the weight of the fore arm and the hand further down.



Fig. 31.—Gastrocnemius Muscle.

(From Wilson's 'Physiology.' W. and R. Chambers, Ltd. By permission.)

The opposite movement of straightening or extension of the fore arm is brought about by the triceps muscle situated behind the humerus. Its origin is by a tendon attached to the scapula and two attachments at the upper end of the humerus. The muscle is inserted at its lower end to the upper end of the ulna (Fig. 27, P') a little above and behind the fulcrum at the elbow joint. In contracting the muscle pulls the upper end of the ulna upwards and thus straightens the flexed arm. In this case, therefore, the ulna acts as a lever of the first order.

When we stand on tiptoe the fulcrum is the ground on which the toes rest, the power required to raise the body off the ground is applied by the muscles of the calf at the point where the tendon of Achilles is inserted on the heel bone, and the weight of the body falls on the bones of the foot. The weight being in the middle, this is an example of a lever of the second order.

Standing, Walking and Running.—We have considered above a few examples of movements of the limbs; it remains now to consider how the body as a whole maintains its erect position and performs such movements as walking, running, jumping, etc. The erect position of the body is secured by a complex arrangement of muscles, in front and behind

the body, which balance each other ; those in front pulling forwards and those behind backward. The weight of the body falls on the tarsal bones of the foot, and there is a tendency for the leg to fall forward. This is counteracted by the great muscles of the calf. The ankle-joint is thus kept stiff ; similarly, the knee-joint is kept from yielding by muscles passing before and behind it. The muscles in front of the thigh pull the body forward, but the muscles of the buttocks tend to pull backwards. The trunk is thus supported at the hip joints by the muscles passing from the trunk to the thigh before and behind. The action of the muscles along the vertebral column would pull the body backwards and this is balanced by those in front of the abdomen and throat. Finally the head is prevented from falling forwards by the action of the muscles at the back of the neck. The combined action of opposing muscles balances the body and keeps it erect.

A baby learning to stand finds considerable difficulty in adjusting the action of all the muscles, but once he has thoroughly learnt it he is able to stand without conscious effort. All the same, the contraction of the muscles is due to the impulses received by them from the central nervous system. A blow on the head or sudden shock to the nervous system not only makes a man senseless but by stopping the nervous impulses from reaching the muscles, causes the latter to relax and the person falls down. The same happens in fainting. Insufficient or improper supply of blood to the brain causes unconsciousness and stoppage of nervous impulses from the brain to the muscles.

In **walking** the body is supported by one foot while the other leg is swung forward. When the advanced foot, say

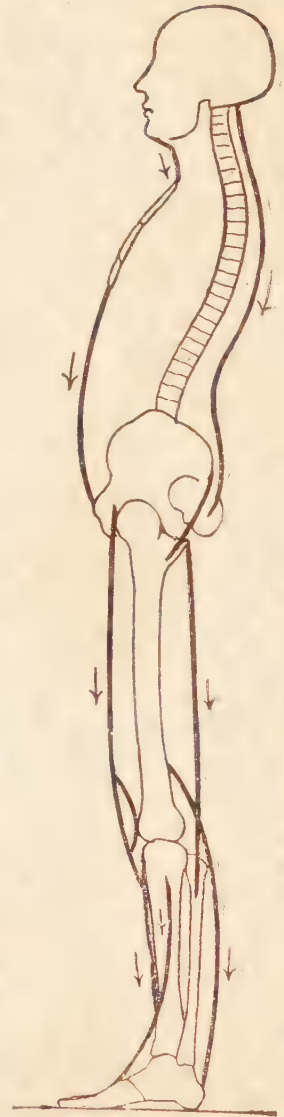


Fig. 32. — Diagram showing opposing muscles which keep the body erect.

(From Thornton's 'Elementary Practical Physiology.' By permission.)

the right, has come in contact with the ground, the calf muscles in the other leg (left) contract, raising the body on the toes. The left leg is raised off the ground and swung forward. As the left foot comes in contact with the ground, the right leg is raised off and swung forward. In walking fast the arms swing in unison with the legs and help to keep the equilibrium.

In **running** the same alternate movements of the legs occur, only the contractions of the muscles are more violent and the movements more rapid. The heels do not come in contact with the ground and for brief moments both feet are raised off from the ground. In **jumping** both legs act together. Contraction of the muscles of both calves and of the muscles of the thighs takes place simultaneously and the body is swung through the air by the sudden extension of the limbs.

CHAPTER VII

FOOD AND ITS COMPOSITION

Food.—Our body is a complex machine which generates heat and energy, repairs waste, and grows in size and weight. It is a machine which is working every moment of its life. The body is kept warm, the heart keeps beating, and breathing, as well as many other actions and processes, of which we are unconscious, are going on in our body. This is the internal work. The external work consists of all our voluntary acts, such as standing, walking, running, talking, etc. For all these processes it needs food. When absorbed into the system the food is capable of being oxidized, i.e., burnt, and thus produces heat and energy. During the various life processes the tissues and cells of the body are constantly breaking down and were it not for the fact that the body is a self-repairing machine, it would soon dwindle and die away. Thus the chief uses of food are :—

- (1) It is the material which supplies heat and energy.
- (2) It makes good the wear and tear of the body.
- (3) It supplies material for growth.

All the various functions of food are not performed by each and every article of our diet. Some of the articles of our food produce heat and energy while others replace waste or cause growth. If we were to analyse the various food-stuffs we find them to consist of a mixture of one or more of the following kinds of substances, every one of which is essential for life.

Proteins.	Vitamins.
Carbohydrates.	Mineral Salts.
Fats.	Water.

The relative proportion of the proximal principles or food-stuffs in certain articles of daily use are given in the accompanying figure.

Proteins.—These are complex compounds of carbon, hydrogen, oxygen, nitrogen and sulphur. As they are the only organic food substances which contain nitrogen, they are

often called **Nitrogenous** food substances. The common foods in which they are found are—in eggs as **albumin**, in meat as **myosin**, in wheat as **glutenin**, in milk as **casein**, and in peas, beans and *dals* as **legumin**.

The use of proteins is to build up the tissues of the body and to repair them

when worn out. Hence they are called **tissue-builders** and are absolutely necessary for the existence and growth of all animals. If taken in excess they may give rise to fat in the body and in the absence of sufficient intake of carbohydrates and fats may help in the production of animal heat.

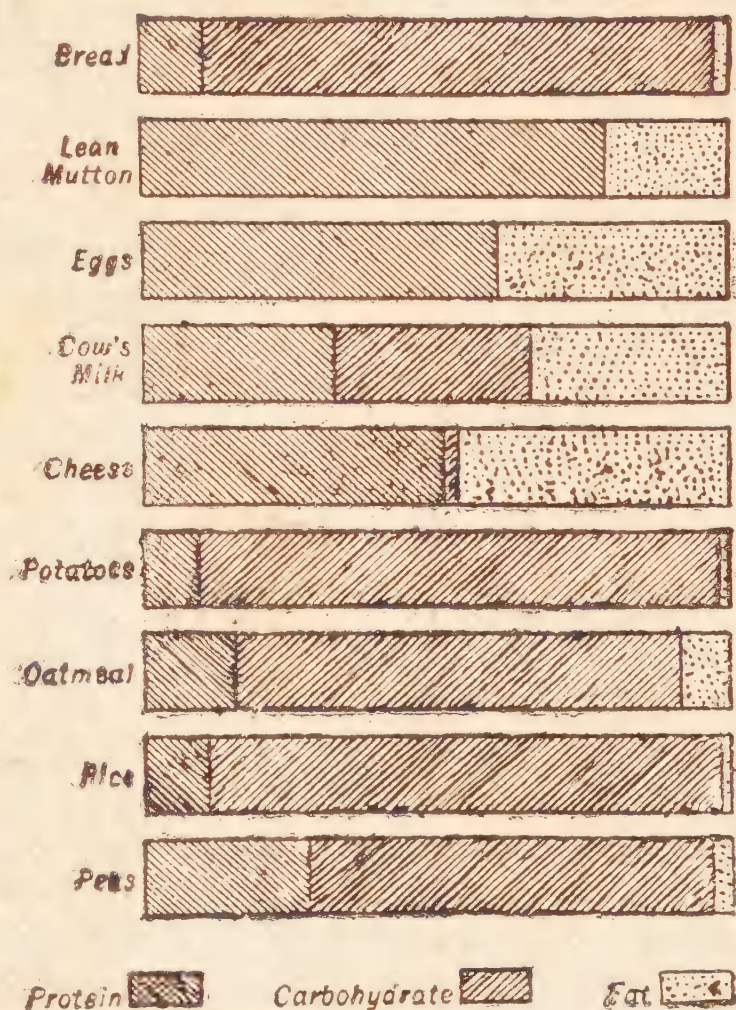


Fig. 33.—Diagram to show the relative proportions of Proteins, Carbohydrates and Fats in common foods.

(From Cathcart's 'First Book of Physiology and Hygiene.' Macmillan & Co. By permission.)

The water and mineral salts are not represented.

cereals, such as wheat, maize, oats, rice and in potatoes. Sugar is obtained from the sugar-cane, beet-root and in the juices of various fruits. However lactose, a kind of sugar, is found in milk, and glycogen, a form of starch, exists in the liver.

Carbohydrates.—These are compounds of carbon, hydrogen and oxygen, the last two being present in the same proportion as in water. Hence, their name 'Carbohydrates'. The carbohydrates are mainly derived from the vegetable world. Thus we get starch in the grains of all

Carbohydrates are used for the production of energy and the maintenance of animal heat, as well as for the formation of fat in the body. They are cheaper than fats and poor people have to depend largely on them as they are, to some extent, interchangeable with fats, but it has been shown that health cannot be properly maintained if fats are entirely excluded.

Fats.—These consist of carbon, hydrogen and oxygen. Every fat is a compound of a fatty acid and glycerine. When a fat is acted upon by an alkali, it forms soap and glycerine—a process called **saponification**. When fat is broken up into minute globules which are suspended throughout a mixture, the process is known as **emulsification**. Fats are derived from both animal and vegetable kingdoms. Butter, *ghee* and various vegetable oils like mustard oil, cocoanut oil, are all examples of fats that are used as food. The use of fats is to produce heat and energy; a given weight of fat produces more heat energy than the same weight of any other food-stuff. If more fat is taken than is required for heat or energy production, it is stored up as fat in the tissues.

Vitamins.—It has long been known that feeding animals only with sufficient quantities of pure proteins, fats, carbohydrates, salt and water does not maintain them in a healthy condition. Such experiments on the feeding of animals led to the discovery of certain substances which must be included in food, in order to maintain life. These substances are called **Vitamins** (*lit.* life-giving substances) or accessory food factors. They are present in all kinds of fresh food and most are destroyed by heat or long keeping. Three kinds of vitamins have been recognized, though it has not so far been found possible to isolate them or to determine their quantity present in any food.

Fat-soluble A-Vitamin, present in certain fats, particularly codliver oil, butter, yolk of eggs and in green leaves. It is however absent from lard and fats of vegetable origin.

Water-soluble B-Vitamin, present in the seeds of plants, the yolk of eggs, many fruits and vegetables, cereals like wheat and rice and in fresh peas and beans. In the case of cereals it is present just under the skin and is removed in the process of milling by machinery.

Water-soluble C-Vitamin is present in most juicy fruits and vegetables.

Each of these three distinct kinds of vitamins must be supplied in our diet, to keep the body healthy and their absence from our food leads to certain diseases. Rickets is associated with a lack of A-Vitamin, Beri-Beri with a diet poor in B-Vitamin, and scurvy with the absence of C-Vitamin.

Mineral Salts.—The common salt (sodium chloride) is largely taken with food, not only because it makes the food palatable, but it is also essential to maintain the health of the body. It is contained in all the tissues and is the source of hydrochloric acid found in the digestive juice secreted by the stomach. Phosphates, especially of lime, are required for the building up of bones and iron salts are needed to form hæmoglobin in the blood. All these salts are present in most kinds of food.

Water is present in all the tissues of the body. It serves to dissolve the food when digested and aids in its absorption, keeps the blood fluid and helps in the removal of excretory products from the body. Water is separated from the blood continually by all the excretory organs, a person losing on an average $3\frac{1}{2}$ to 5 pints of water per day from the kidneys, lungs, skin and intestines. This is replaced by water in the food. About a pint is obtained from the solid food, the rest being made good by drinking water.

Summary of Food-stuffs and their uses in the body.

Proteins, e.g. the albumin of eggs, the casein of milk, the myosin of meat, the glutenin of bread, **form tissues.**

Fats, e.g. the fat of meat, the butter of milk, the oil of seeds, **are stored as fats.**

Carbohydrates, e.g. the starch of bread, the sugar of sugar-cane, beet-root, milk, fruits, **are stored as fat or as glycogen in the liver.**

All these may also serve as fuel and be oxidized, thus furnishing heat and energy for muscular work, but fats and carbohydrates are mainly used as fuel.

Salts

e.g. sodium chloride (common salt), the phosphates of lime, soda and potash.

} Needed for forming bone, and as constituents of digestive juices.

Water

• taken as such and as a component of all solid foods.

} Serves to dissolve the food-stuffs and to convey them to different tissues ; aids in the removal of waste ; takes part in tissue-formation.

Vitamins

• in all kinds of fresh animal and vegetable foods.

} Necessary to keep the body in a healthy state.

Articles of food.—For the composition of some of the common articles of food, the student is referred to the author's *Elementary Hygiene*.

Essentials of a Good Diet.—A man doing ordinary work needs on an average 4 oz. of proteins, 14 oz. of carbohydrates, 3 oz. of fat and $1\frac{1}{2}$ oz. of salts every day. There is no article of food except milk which contains these ingredients in the required proportions, and even in the case of milk, these are so highly diluted with water that a man will need a very large quantity to supply the necessary amount of carbohydrates to the body. This difficulty is easily overcome by taking articles of high protein value along with those containing a high percentage of carbohydrates and adding to them a certain amount of *ghee* or butter. Both experience and science tell us that a mixed diet is the most suitable for health and comfort. Thus we eat *dal roti*, or rice and *dal*, or rice and fish, or meat and potatoes, adding to them butter or *ghee*. The diet should vary with the work, weight and age of the individual. A man who works hard needs more proteins to repair the greater waste of his tissues and more fats and carbohydrates to supply energy used in doing the work. Children need a relatively larger proportion of food to body weight than the adults. Their bodies are growing and they are also more active and restless.

Food should be easily digestible and properly cooked, as it is obvious that indigestible food cannot be assimilated by the body. Thus although peas, beans and *dals* contain a high percentage of proteins, the protein is more difficult to digest than that of animal foods like eggs or meat, and

much of it passes off in the fœces unused. The vegetable food also contains a large proportion of indigestible cellulose. In general, for the building of muscle protein, the flesh of animals is the best food. The vegetarians also usually take some animal protein, e.g., milk, cheese, or eggs, but a purely vegetarian diet may suffice if rightly selected. Mixtures of seed, nut and leaf proteins, may contain all that is essential in that direction.

CHAPTER VIII

THE PROCESSES OF DIGESTION

Digestion is the process of splitting up the various food-stuffs into simpler products which can be absorbed into the blood circulation. The digestive system consists of a long tube of varying diameter and of certain glands which pour their secretions into it. This tube is called the **Alimentary Canal**. It begins at the mouth, into which cavity is poured the secretion from the salivary glands. As it passes backwards it expands into a funnel-shaped cavity called the **Pharynx**. In the pharynx the openings of the nostrils, the eustachian tubes from the ears and the upper end of the wind-pipe are also situated. The tube then narrows into a soft muscular tube about ten inches long, called the gullet or the **Oesophagus**. This passes down the neck into the chest, lying behind the wind-pipe, pierces the diaphragm, and opens into the stomach. The **Stomach** is a large bag lying a little to the left just under the diaphragm. It has two openings, one where the gullet ends, called the cardiac opening, as it is nearest the heart, and the other where the intestines begin, known as the pyloric opening. The alimentary canal narrows again and passes into the **Small Intestine** which is about twenty-two feet in length. The first ten inches of the small intestine, the **Duodenum**, forms a C-shaped loop, in the concavity of which lies an important gland, the **Pancreas**. Into this part open the ducts of the liver and the pancreas. The rest of the small intestine lies in the abdomen as a coiled-up tube. The small intestine at its end opens into a wide but comparatively short tube known as the **large intestine**. It is about six feet long. Just below the junction of the small with the large intestine, the latter has a blind pouch, the **caecum**. A narrow blind tube, the **Vermiform appendix** about four to six inches long, hangs down from the caecum. The caecum occupies the right lower end of the abdomen and the part of the large intestine above it is called the **Colon**. The colon, just passes up on the right side, then crosses the abdomen just under the liver and the

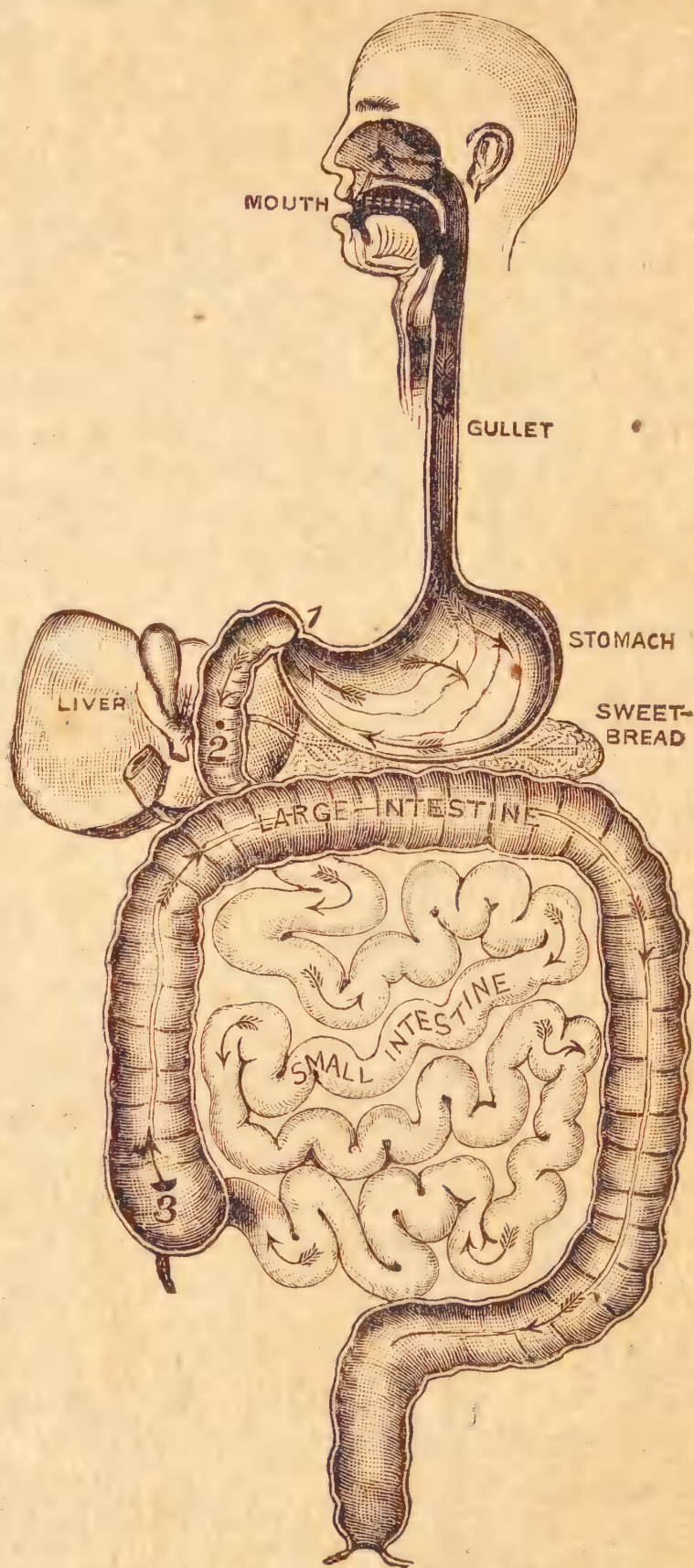


Fig. 34.—General view of the Alimentary Canal, the Liver being turned up.

(From Paul's 'Domestic Economy.' By permission.)

1, pylorus, the opening between stomach and duodenum; 2, opening of the common duct of the liver and pancreas (sweetbread) into duodenum; 3, opening between the small intestine and the large. Large intestine consists of ascending colon, transverse colon, descending colon and rectum leading outside.

stomach and lastly descends on the left side, these portions being known as the ascending colon, the transverse colon and the descending colon. The descending colon passes into a straight tube, the **Rectum**, which opens to the outside by the **Anus**.

The Mouth Cavity.—The mouth cavity is the anterior expanded end of the alimentary canal. The sides of this cavity are formed by the cheeks, the roof by the palate, the floor by the tongue, while when closed it is bounded in front by the upper and the lower sets of teeth meeting in the middle. The opening at the back of the mouth is known as the throat, on each side of which there is a mass of tissue called the **tonsils**.

The Teeth.—The teeth are provided for the proper chewing of food and during our life time two sets are developed, (1) the temporary or milk teeth and (2) the permanent teeth.

The temporary teeth are twenty in number. They begin to appear at about the age of six months. They are usually smaller and more delicate than the permanent set. The first to appear are the two middle teeth, the **central incisors** in the lower jaw. The set is usually complete

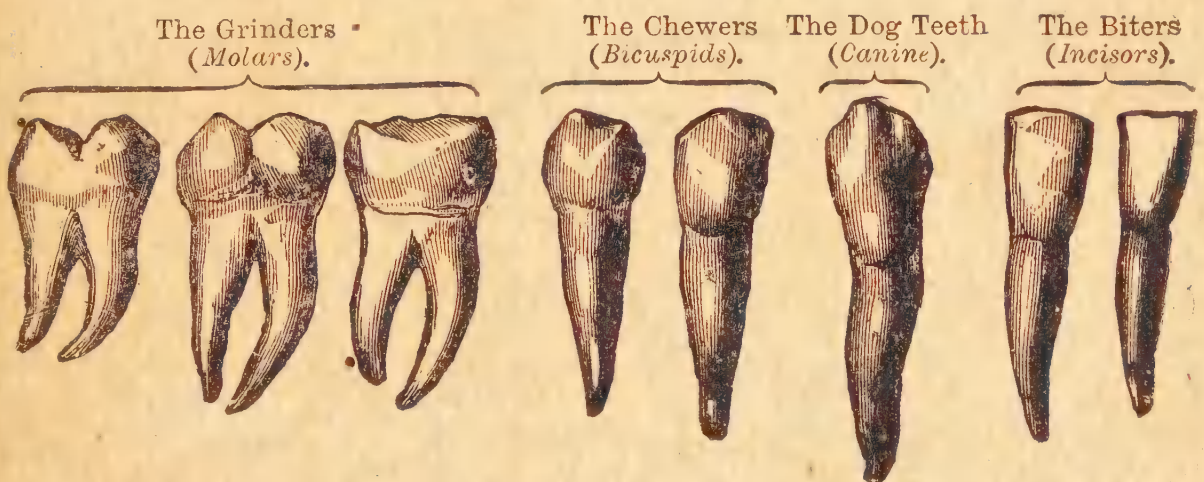


Fig. 35.—Different kinds of teeth.

(From Gray's 'Anatomy.' By permission.)

The figure shows the eight teeth found in each half of the upper and the lower jaw. There are two incisors, one canine, two bicuspids and three molars shown in the figure. There are actually four times as many of each in the whole set of teeth.

before a child is three years old, and consists of two **incisors**, one **canine**, and two **molars** in each half of each jaw, that is, twenty teeth in all. They begin to drop out about the seventh year and are all gone at twelve.

The teeth of the permanent set appear gradually and as they appear push out the temporary teeth. They are thirty-two in number, as in addition to the teeth corresponding to the temporary set, there are three molars in the upper and the lower jaw on each side.

By the fourteenth year all teeth of the permanent set have appeared except the last four molars. These are called wisdom teeth as they appear after a person is twenty-one years of age.

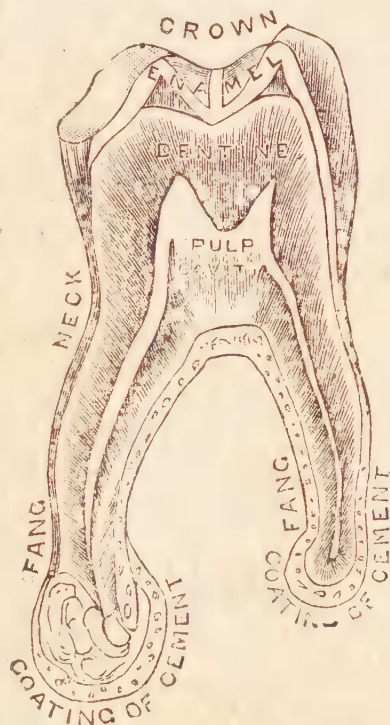


Fig. 36.—Section of a Tooth.

(From Barnett's
'Making of the Body.'
By permission.)

Structure of Teeth.—The teeth are set in the jaws, the part of a tooth inside the socket is known as the **fang** and the part above the gum is called the **crown**. The incisors and canines have only one fang each, while the premolars or bicuspsids have two, and the molars or tricuspsids three fangs.

A tooth has a central cavity containing blood-vessels, nerves, etc., called the **tooth-pulp**. Outside it on the crown of the tooth, there is a very hard substance called the **enamel** while over the fang there is the hard **cement** substance which fixes the tooth to the socket.

The function of the teeth is to cut, crush and grind the food, the process being known as chewing or mastication. This is effected by the lower jaw working against the upper by means of certain muscles attached to it.

Salivary Glands.—During mastication the food is not only ground but mixed with a fluid called **Saliva** which is secreted by the salivary glands. They are six in all, three on each side. The **parotid gland** (*lit.* near the ear gland) lies in front of the ear, the **submaxillary gland** under the lower jaw, and **sublingual gland** under the tongue. The saliva is brought from the glands by ducts which open into the mouth cavity.

Journey of the Food.—Let us now see what happens to the food, from the moment it is put in the mouth. The food as

it enters the mouth (and even the smell, the sight or the thought of food) stimulates the secretion of saliva, which is poured into the mouth. The teeth masticate the food and break it into small pieces, while the tongue thoroughly mixes the saliva with the food.

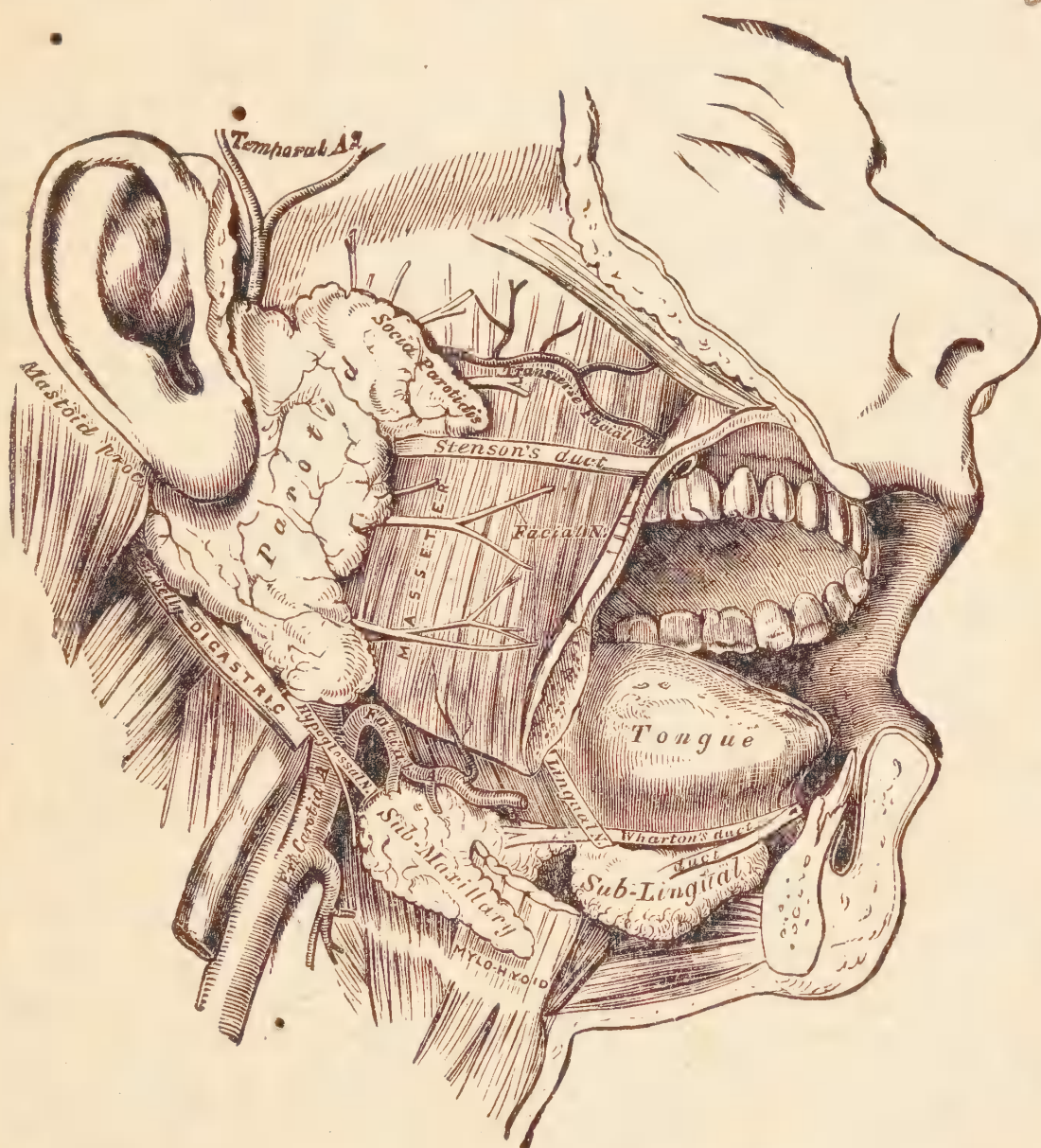


Fig. 37.—The Salivary Glands.

(From Gray's 'Anatomy.' By permission.)

One side of the lower jaw has been removed and the face dissected, in order to show the salivary glands on the right side.

The saliva is an alkaline, watery fluid, and contains a ferment known as **ptyalin**. Ferments are substances which have the power of bringing about profound chemical changes in the substances on which they act, without changing themselves. Thus the ferment ptyalin contained

in the saliva changes the starchy matter in the food into a sugar called maltose. The insoluble starch is thus partly converted into a soluble and easily absorbable sugar, while the food is still in the mouth. The longer a morsel of food is chewed in the mouth, the better will it get mixed with the saliva. It is important therefore to chew your food well, and to keep it long enough in the mouth to get the starch changed into sugar. If you take some cooked rice or a morsel of bread in your mouth, and chew it well, you will find that it becomes slightly sweet in taste. This is because the starch in it has been changed into sugar.

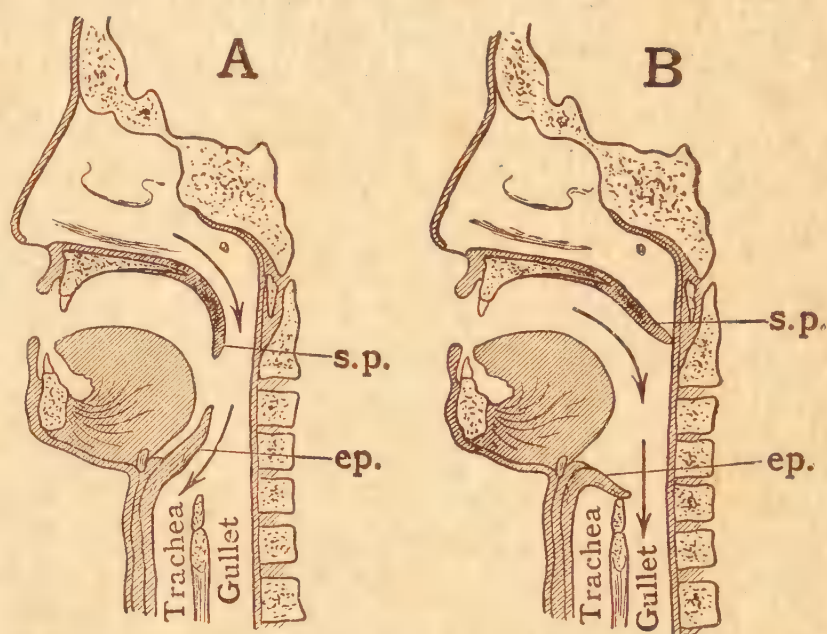


Fig. 38.—Showing the position of the soft palate (s. p.) and epiglottis (ep.) during (A) breathing and (B) swallowing.

(From Thornton's 'Elementary Practical Physiology.'
By permission.)

In A the arrows indicate the passage of air, and in B the passage of the food.

The food after it has been masticated, is gathered into a ball or bolus and sent down the pharynx into the gullet or œsophagus (Fig. 38, B). In front of the gullet is situated the wind-pipe (the passage for the air) and the food is prevented from going into that tube, by the tube being drawn up, and the lid-like epiglottis falling down and for the moment closing the entrance to it (Fig. 38, B). If a particle of solid food or water should go the wrong way, and get into the wind-pipe, it is expelled by violent coughing.

The food passes down the gullet by the action of its muscular walls, which contract above it and push it along. Food does not simply fall down the gullet, but each part of the gullet contracts after the part next above and so squeezes the food along till it passes through the cardiac opening and enters the stomach. We shall next consider the structure of that organ and the changes that take place while the food is in the stomach.

The Stomach.—The stomach is a bag-like expansion of the alimentary canal, with its broad end to the left and narrow end to the right. The stomach is lined with mucous membrane which is smooth when the stomach is full, but becomes thrown into ridges when it gets empty. In the mucous membrane are a very large number of minute blind tubes arranged side by side, and running at right angles to its surface. These are tubular **gastric glands**. On looking at the inner surface of the stomach with a lens, we can see the tiny holes which form the mouths of these gastric glands. Between the tubules is connective tissue containing blood-vessels and lymphatics. When the food enters the stomach, the blood-vessels dilate and bring extra blood to the stomach. Then the cells forming the tubular glands secrete from the surrounding lymph, a colourless liquid called the **gastric juice** (Gk. *gaster*, the stomach). The gastric juice is poured into the cavity of the stomach and mixes with the food. Outside the mucous coat of the stomach is the muscular coat, which is divisible into three layers according to the direction of the muscular fibres composing it. This coat helps by its contraction to churn the food round and round, and enables it to mix thoroughly with the gastric juice. The outermost coat of the stomach consists of a smooth, glistening membrane, which is common to all the organs in the abdomen, and is known as the peritoneum.

Gastric Juice is a colourless, acid liquid, containing water, a minute quantity of salts, a little hydrochloric acid (0·2 per cent, i.e., two parts in 1,000 of the juice), and two ferments called **pepsin** and **rennin**. For some fifteen to twenty minutes after the food enters the stomach, the action of the saliva continues on the starchy portion of the food. The gastric juice has by that time been secreted in sufficient quantity to render the contents of the stomach acid and to stop the

action of the ptyalin which can act in an alkaline medium only. **Rennin** ferment of the gastric juice coagulates milk and precipitates casein which is then acted upon by the pepsin. The **pepsin** in the presence of hydrochloric acid acts upon the proteins of the food and changes them into simpler substances called **peptones**, which are soluble and easily diffusible. The gastric juice has no action upon the carbohydrates or the fats of the food. The time taken by the gastric digestion varies with the kind of food, but averages from three to four hours. After the food has been thoroughly acted upon by the gastric juice, the stomach would contain starchy portions of the food changed into sugar, starchy portions unchanged, proteins changed into peptones, proteins unchanged, melted fat, indigestible portions of food, all mixed with gastric juice. This acid mixture of gastric juice and partly digested food is called **chyme**. Some of the sugar and peptone is absorbed into the blood-vessels of the stomach. The greater part of the chyme passes into the duodenum through the pylorus. The pyloric opening is surrounded by a band of circular muscles, which remains contracted and prevents food passing from the stomach, until it has been thoroughly churned up with the gastric juice. Finally it relaxes and allows the chyme to pass into the duodenum, where it is acted upon by the secretions of the pancreas, the liver and the wall of the small intestine.

Digestion in the Small Intestine.—The first part of the small intestine is the **duodenum**, forming a C-shaped loop. A duct from the liver called the bile duct and a duct from the pancreas known as the pancreatic duct unite to open together into the lower portion of the duodenum (Fig. 39). The bile duct brings bile and the pancreatic duct pancreatic juice, and these two fluids mix with the chyme and carry on the process of digestion a stage further.

The **pancreatic juice** is an alkaline colourless liquid and contains three ferments, **amyllopsin**, **trypsin** and **steapsin** or **lipase** which digest the carbohydrates, proteins and fats respectively. Amylopsin has an action similar to that of ptyalin and changes any starch that has escaped the action of saliva, into sugar. Similarly trypsin acts upon proteins that have not been acted upon by the gastric juice and changes them into peptones, but the important difference

is that while pepsin acts in an acid medium trypsin brings about the same action in an alkaline one. The third ferment lipase acts upon fats, splitting fat into fatty acid and glycerine that compose it. The fat splitting action of lipase is greatly facilitated by the presence of bile. The digestion of the fats is further aided by the formation of soaps. Some of the fatty acid which is set free combines with the alkalies of the intestinal contents to form soap (just as ordinary soaps are formed by the union of fatty acids and alkalies). This soap surrounds the remaining particles of fat and thus makes a still finer emulsion of them, the fine particles remaining suspended in a liquid mass.

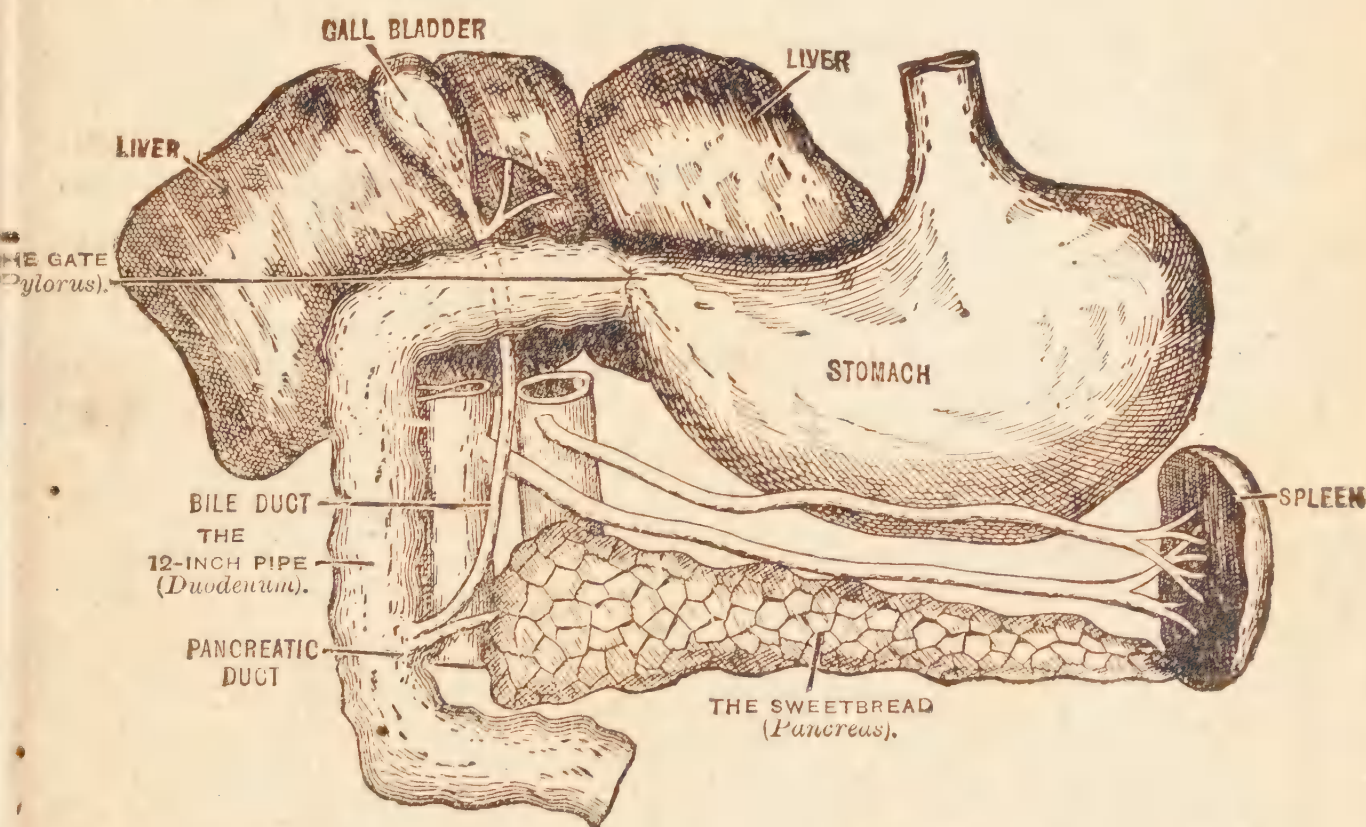


Fig. 39.—The Stomach, Duodenum, Liver, Gall-bladder, Pancreas, and Spleen.

(From Furneaux's 'Human Physiology.' By permission.)

The bile duct and the pancreatic duct are seen to open together into the duodenum.

The formation of the pancreatic juice chiefly takes place after the passage of the acid contents of the stomach into the duodenum. It has been shown that some substance formed by the action of the acid on the intestinal epithelium, is carried in the blood-stream to the pancreas.

This substance is called **secretin** and acts as a chemical messenger to rouse the pancreas to activity.

The **bile** from the liver has no direct digestive action, but it aids the pancreatic juice in its action on fats. It has important antiseptic properties and keeps down the bacterial contents in the intestines. It also promotes the absorption of the products of digestion.

Intestinal Juice.—The completion of the digestive process is the work of the intestinal juice which is secreted by the tubular glands occurring in the mucous membrane of the small intestine. It completes the digestion of starches and proteins, begun by the salivary and carried on by the gastric and pancreatic secretions. Thus the maltose which was formed by the action of ptyalin and amylopsin on starch is changed into the simpler sugar glucose by the action of a ferment. The peptones formed by the action of pepsin and trypsin on proteins are converted into simpler end products called **amino-acids** by the action of **erepsin**. In addition to these, the intestinal juice contains two other ferments which convert the complex cane sugar and milk sugar into glucose and other simple sugars.

By the time the food goes out of the small intestines it is completely changed into the simpler end products, that is to say, completely digested. The carbohydrates have all been changed into simpler sugars, the proteins into amino-acids and the fat into fatty acids and glycerine. The intestinal contents are slowly propelled along the gut and at the same time thoroughly mixed up. The onward movement of the food is effected by means of waves of constriction of the intestines called **peristalsis**. These can easily be seen in a living animal by means of X-rays or immediately after death, if the intestines are kept moist.

Absorption of the Digested Food.—The food that has been digested or changed into a soluble form is then absorbed into the blood. This absorption chiefly takes place in the small intestine, but to a smaller extent in other parts of the alimentary canal also. The small intestine is lined with mucous membrane, which along the greater part of its length is thrown into circular folds (Fig. 40) which increase the surface from which absorption can take place. The

mucous membrane is further covered with innumerable minute projections, called **villi** (Fig. 41) rising from it like the pile of velvet. Under the microscope, each villus is seen to be covered with a layer of cells and contains in its interior, blood vessels, lymphatics, nerves, etc. The lymphatics that thus begin in the villi are called **lacteals** (Fig. 42).

These villi absorb the digested food. The sugars and amino-acids are absorbed by the blood capillaries and the

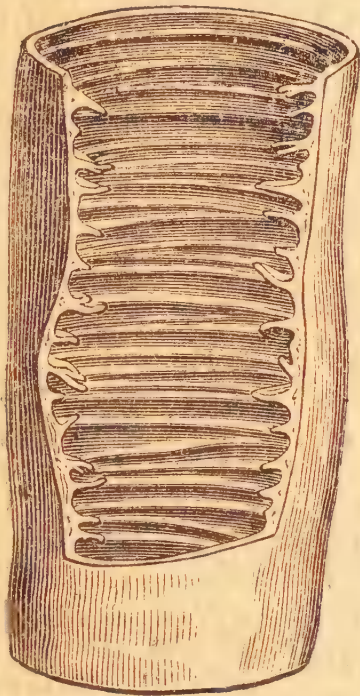


Fig. 40.—Portion of Small Intestine cut open to show folds of Mucous Membrane.

(From Quain's 'Anatomy.' By permission.)



Fig. 41.—A small portion of the Mucous Membrane of the Small Intestine.

(From Todd's 'Cyclopædia.' By permission.)

(Magnified 12 diameters)

a, patches surrounded by tubular glands;

b, villi; c, openings of tubular glands.

fats by the lacteals. The milky fluid absorbed by the lacteals during digestion is called **Chyle**. The blood capillaries from the various villi unite to form veins, and veins from the stomach, the small and the large intestines uniting together form a large vein, called the **portal vein**, which goes to the liver, on entering which it again breaks up into capillaries. Thus all the carbohydrates and proteins of the food, after digestion and absorption pass through the liver and any excess of carbohydrates in the blood beyond the requirements of the body, is stored up in the liver, by

being re-converted into a form of starch known as **glycogen**. The lacteals also unite with one another, to form lymphatics which lead to lymphatic glands, from whence other lymphatics continue to carry the fatty emulsion till they open into a large lymphatic vessel known as the **thoracic duct**. The thoracic duct finally enters into the blood stream, at the junction of the two veins at the root of the neck, on the left side of the body.

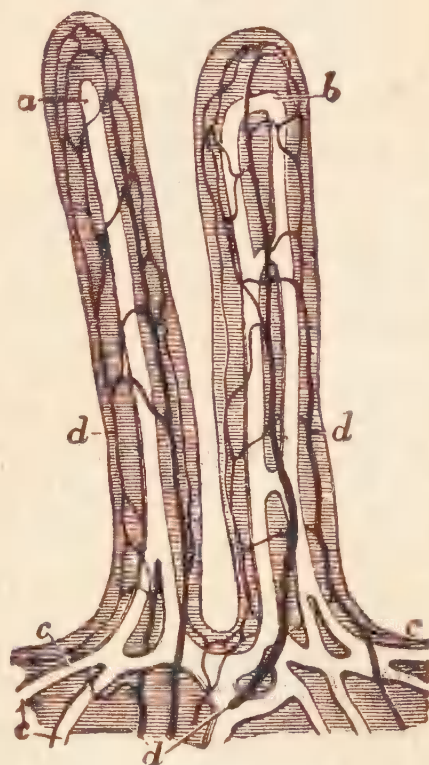


Fig. 42.—Two villi.

(From Quain's 'Anatomy.'
By permission.)

(Magnified 100 diameters)
a, b, and c, lacteals for absorbing fat; d, blood vessels which absorb other digested food-stuffs.

Most of the digested food having been absorbed in the small intestine, a semi-fluid mass is left to pass into the large bowel. The large intestine absorbs any matter that can still be absorbed as well as a large amount of water. The contents of the large intestine thus become firmer and the part ultimately thrown out, the fæces, consist largely of the undigested and the unabsorbable portion of the food, as well as the remains of digestive juices, cast off cells, bacteria, etc. The large intestine, in spite of the disinfecting powers of the bile, is full of bacteria especially *Bacillus Coli*, which set up processes of decomposition and putrefaction and give rise to the bad odour of the fæces.

The amino-acids are changed on entering the blood into proteins, the fatty acid and glycerine are combined again to form fat droplets, while the simple sugars (glucoses) are absorbed as such and are found in the blood stream.

CHAPTER IX

THE LIVER, PANCREAS AND SPLEEN

As seen in the preceding chapter closely associated with alimentary canal are two important organs, the liver and the pancreas, secretions from which are brought by special ducts and poured into the duodenum, to help in digestion. We shall now learn some further facts about these, as also about the spleen which is placed to the left of the stomach (Fig. 39).

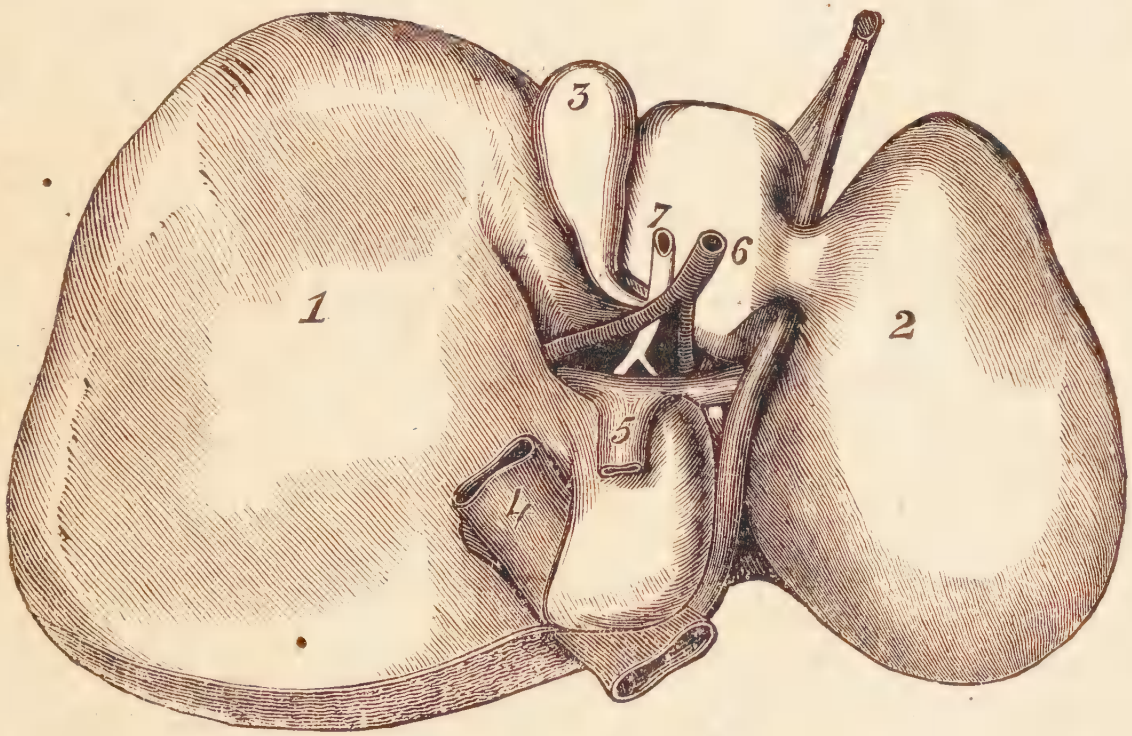


Fig. 43.—The under-surface of the Liver.

(From Furneaux's 'Human Physiology.' By permission.)

1, right lobe ; 2, left lobe ; 3, gall bladder ; 4, inferior vena cava ; 5, portal vein entering the liver ; 6, hepatic artery ; 7, hepatic duct.

The Liver.—The liver is the largest gland in the body. It is a reddish brown organ weighing about $3\frac{1}{2}$ lbs. It extends almost across the abdomen, on the right side fitting closely the arch of the diaphragm and extending to the left, slightly overlapping the stomach. A fissure

divides the liver into the right and the left lobe. On the under-surface of the liver is a pear-shaped bag, the **gall bladder**, in which the bile secreted by the liver is collected (Fig. 43).

The blood supply of the liver is peculiar. As already stated the portal vein (Fig. 43, 5) coming from the alimentary canal breaks up into capillaries in the liver and these capillaries again unite to form the hepatic veins which open into the Inferior Vena Cava. In addition to the portal vein, the liver gets blood from the hepatic artery (Fig. 43, 6) which is a branch from the aorta and nourishes the liver cells.

Coming out of the liver is a large tube, the **hepatic duct** (Fig. 43, 7) which brings bile from the organ. While passing down it gives a branch which goes to the gall bladder carrying bile to be stored up till actually required for digestion. Further on the duct is known as the **common bile duct** and opens in to the duodenum along with the duct from the pancreas (see Fig. 39).

Functions of the Liver.—It has been mentioned above that the portal vein brings to the liver blood which after a freshly digested meal, is rich in food materials. Out of these, some of the sugar is converted by the liver into glycogen and stored in it, so that the blood going from the liver does not contain any extra amount of sugar over that usually found in the blood. Between meals the sugar in the blood is used up by the body in producing energy and heat, but the amount of sugar in the blood is kept up, by the liver gradually changing the glycogen back into sugar, according to the needs of the body. Other functions of the liver are to secrete bile which aids the digestion of food, acts as an antiseptic and as a laxative; and to destroy any poisonous substances absorbed from the intestines. Yet another function of the liver is to manufacture urea from the products of protein destruction during muscular and glandular activity. This urea goes into the blood and is finally excreted by the kidneys.

The Pancreas.—The pancreas or sweetbread is a long narrow gland. It lies in the bend of the duodenum on the right and extend to the spleen on the left. Its duct opens into the duodenum along with the common bile duct. The pancreas secretes a clear colourless juice which has the important digestive properties described above. In addi-

tion to the pancreatic juice, the pancreas produces a secretion which is absorbed into the blood stream and hence called an **internal secretion**. This internal secretion helps the tissues to burn up the carbohydrates and if the internal secretion is absent or deficient, the carbohydrates are not burnt properly, but accumulate in the blood and sugar appears in the urine. This appearance of sugar in the urine due to the deficiency of the internal secretion of the pancreas is called **Diabetes**.

The Spleen.—The spleen is the bluish-red organ situated to the left of the stomach and pancreas (see Fig. 39). It is covered by a special capsule of its own, but its substance is soft and spongy. The soft pulpy substance consists of blood corpuscles (both red and white) and some large-branched cells contained in the meshes of fibrous bands. The spleen is well supplied with blood by the splenic artery and the large splenic vein carries the venous blood to the portal vein which goes to the liver.

The functions of the spleen are not fully known. Two functions of the organ are however well known. In the spleen the white corpuscles are formed. Secondly the old and worn out red corpuscles gradually break up by being entangled in the spleen pulp and are thus removed from the blood. The spleen is thus known to be 'the birth place of the white corpuscles and the grave-yard of the red.' In many infective diseases the spleen is enlarged and it seems to protect the body by removing micro-organisms from the blood and destroying the poisons formed by them. After continued attacks of malarial fever, the spleen is greatly enlarged but comes back to the normal size if the patient is carefully treated. Being spongy in character spleen is able to retain large amount of blood and on account of rhythmic contractions acts as an important vascular reservoir.

Ductless Glands.—Ductless glands are organs which have some resemblance to a gland, but have no duct. The product of their activity passes into the blood stream and is on that account called an **internal secretion**. Two ductless glands, viz. **thyroid gland** and the **supra-renal bodies** may be mentioned here. The thyroid gland is situated in the front of the neck, just below and on each side of the larynx and its enlargement is known as **goitre**. The supra-renal bodies lie in the abdomen, one on the top of each kidney. It is

difficult to state briefly and clearly what is known of the functions of these bodies. In general it may be said that the internal secretions of various glands are essential to health and even life, and that they regulate the functions of distant organs to which they are carried through the blood stream.

CHAPTER X

THE BLOOD

The Blood.—Blood is the fluid medium which brings oxygen and nourishment to all parts of the body and removes the waste products formed in them. It consists of an almost colourless fluid called **plasma** in which float myriads of small bodies called **corpuscles**. Under the microscope these corpuscles are seen to be of two kinds, (1) the **red corpuscles** and (2) the **white** or **colourless corpuscles**.

The **Red Corpuscles** are minute circular discs, both surfaces of which are concave. They are so small that if placed flat, edge to edge, about ten millions would be required to cover a square inch. When examined under the microscope they are individually seen to be pale yellow in colour, but they are so numerous, that they give to the blood its red appearance. A large number of them arrange themselves in rouleaux, like piles of coins (Fig. 44). In structure the red corpuscles resemble a sponge, being made of an elastic envelope containing a red pigment called **haemoglobin**. Hæmo-



Fig. 44.—Blood as seen under the microscope.

(From Thornton's 'Elementary Practical Physiology.' By permission.)

Red corpuscles are seen in piles and singly; also three white corpuscles.

globin has a great attraction for oxygen with which it readily combines, as in the lungs, to form **oxyhaemoglobin**, which is bright red in colour. But this union is very feeble and the oxygen is readily set free in the tissues when the blood circulates through them. Thus the function of the red blood corpuscles is to carry oxygen from the lungs to the tissues. In the developing young one, before birth, these cells are formed in the liver and the spleen while in adult life they are formed in the bone marrow.

The **White Corpuscles** are colourless and irregular in shape. They are also called leucocytes. They are far less numerous than the red corpuscles being in the ratio of 1 to 500 or 600. They are constantly changing their shapes and thus resemble a minute microscopical animal **amoeba** found in pond water. Consequently their movements are described as **amoeboid movements**. By means of these movements they are capable of moving from one place to another and even



Fig. 45.—Blood Corpuscles, as seen under a microscope, more highly magnified.

(From Quain's 'Anatomy.'
By permission.)

r, red corpuscles lying flat; *r'*, red corpuscles seen edge-wise (bi-concave); *r''*, red corpuscles arranged in rouleaux; *p* and *g*, colourless corpuscles.

of getting out through the thin walls of the smallest blood-vessels. They are also able to take up particles of foreign matter such as disease germs and thus act as guards of the body. In cases of infection with disease germs, the white corpuscles gather round the germs and try to eat them up. They are formed in the bone marrow, lymph glands and other lymphoid tissue in the spleen, intestines, etc.

The **plasma** is transparent pale yellowish fluid in which the corpuscles float. It consists of 90 per cent water and 10 per cent of solids in solution. The solids are various proteins, inorganic salts, of which sodium chloride is the chief, and a small quantity of fat. Besides

these the blood also contains certain gases, chiefly carbon dioxide and oxygen. The former is chiefly in the plasma, while the latter as mentioned above, is carried in loose chemical combination with the hæmoglobin of the red corpuscles. Thus all the substances from which the different tissues of the body are built up, are contained in the blood.

left arm, arise directly from the arch of the aorta. The aorta gives off various arteries to the muscles of the thorax as also to the gullet and the tissues of the lungs.

The aorta pierces the diaphragm and passes down the abdomen. In the abdomen it supplies branches to the diaphragm and to the various organs contained in the abdomen. One short branch divides into three—the **gastric artery** for the stomach, the **splenic artery** for the spleen, and the **hepatic artery** for the liver. Two **mesenteric arteries** supply blood to the mesenteries and the different parts of the intestines. The arteries supplying the stomach and the intestines are represented only in a diagrammatic manner in the coloured plate on the opposite page, the venous blood from these parts is shown as collecting together and passing to the liver. Two **renal arteries** are given off to the kidneys and the aorta finally divides into two great trunks—the **common iliac arteries**. Each of the latter divides into two branches the inner supplying the organs lying in the pelvis and the outer continued down the thigh as the **femoral artery**, and supplying branches to all parts of the leg.

Fig. 54.—General view of the Circulation of Blood. See coloured plate opposite.
(From Thornton's 'Elementary Practical Physiology.' By permission.)

Chambers of the heart and blood-vessels carrying pure blood are represented red, those carrying impure blood as blue. Tr., trachea; L.A., L.V., left auricle and left ventricle; R.A., R.V., right auricle and right ventricle. *a. a.*, arch of aorta; *in. a.*, artery dividing into right subclavian and right carotid; *l. c. a.*, left carotid artery; *l. s. a.*, left subclavian artery; *b. a.*, brachial artery; *r. a.*, radial artery; *u. a.*, ulnar artery; *d. a.*, descending aorta; *st.*, blood-vessels of the stomach; *i. b.*, intestinal-vessels; *Liv.*, blood-vessels of the liver; *f. a.*, femoral artery; *j. v.*, jugular vein; *r. s. v.*, right subclavia vein; *s. v. c.*, superior vena cava; *f. v.*, femoral vein; *h. v.*, hepatic veins; *i. v. c.*, inferior vena cava; *p. a.*, pulmonary artery; *p. v.*, pulmonary veins.

In the various parts and organs of the body, the smaller arteries break up into capillaries and changes mentioned before take place in the character of the blood. Nutrient substances and oxygen pass out, through the thin capillary walls to the tissues, and waste matters and carbon dioxide enter the blood stream, the blood thus changing from a scarlet to a dark colour, that is from pure arterial to impure venous blood. The capillaries unite to form small veins and the small veins open into larger ones, which ultimately return the impure blood from all parts of the body to the

right auricle. Thus right and left **jugular veins** from the head and neck, and the right and left **subclavian veins** from the arms, all unite as shown in the diagram (Fig. 54) to form the **superior vena cava**, which opens into the right auricle. The veins from the legs unite to form the **inferior vena cava**, which runs up through the abdomen, receiving the **renal veins** from the kidneys and **hepatic veins** from the liver. The veins from the stomach, intestine, spleen and pancreas unite to form the **portal vein** which enters the liver and breaks up into capillaries. Thus the liver receives arterial blood by the hepatic artery and blood laden with products of digestion by the portal vein. Both these streams mingle, and blood is returned from the liver by the hepatic veins which open into the inferior vena cava. The latter passes up through the diaphragm and opens into the right auricle. Thus impure blood from all parts of the body is brought back to the right auricle. From the right auricle the blood goes into the right ventricle and by the contraction of the latter, is sent through the **pulmonary artery**, which divides into two, one going to each lung. In the capillaries of the lungs, the impure blood loses carbon dioxide and water vapour, and obtains fresh supply of oxygen. This oxygenated blood is returned by two **pulmonary veins** from each lung to the left auricle, from where it goes into the left ventricle, thus completing the round on which it started. It should be particularly noticed that unlike other arteries the pulmonary arteries carry impure blood (hence represented blue in the diagram) and unlike other veins, the pulmonary veins return pure blood to the heart (hence represented red). The muscular walls of the heart do not use any of the blood contained in the chambers of the heart, but get their supply from two **coronary arteries** (Fig. 48) which arise from the aorta just beyond the semilunar valves. These arteries divide into capillaries in the substance of the heart and the capillaries unite to form a **coronary vein** which opens directly into the right auricle.

Proofs of Circulation.—William Harvey was the first to prove in the seventeenth century that the blood circulates in the body. The proofs now known may be briefly stated as follows:—

(1) The spurting of blood from the arteries corresponds to the beats of the heart.

(2) The valves in the heart, the aorta, the pulmonary artery, and the valves in the veins are so arranged as to allow of the passage of blood in one direction only.

(3) Poisons injected into a single blood-vessel (e.g., when a snake bites a person) soon produce an effect on the whole body.

(4) If an artery is tied in a living body, it swells up on the side of the heart and becomes empty on the other side. If an artery be cut, the bleeding may be stopped by applying pressure on the part above the wound, i.e., on the side nearer the heart.

(5) If a vein be tied it swells up on the side away from the heart. So when a vein is cut, the bleeding is stopped by pressing on the portion below the wound.

(6) The blood may actually be seen moving, by looking at the web of a frog's foot under the microscope. The blood with the corpuscles contained in it, will be seen running in one direction through a small artery, into a network of capillaries and in the opposite direction into a small vein.

Regulation of the Frequency and Force of the Heart Beats.—In a recently-killed frog, the heart keeps on beating for some time, showing that the heart muscle itself has the power to contract and relax, without any impulses from the nervous system. But in the living body, this property of automatic movement is under the control of the central nervous system. Thus strong emotions like fright or shock may make the heart beat quicker, the influence in this case being purely nervous. A pair of nerves called the vagus arising from the brain and passing down the neck into thorax and abdomen, send branches to the heart, which exercise a restraining influence and slow the rate of heart beat. During exercise a more rapid blood supply from the heart is needed. So the vagus diminishes its restraining influence and the heart beats faster. The heart is also connected with the spinal cord through nerves called the sympathetic nerves which increase the frequency and force of the heart. Thus rapid beating of the heart may be due, either to the removal of the restraining influence of the vagus or to the stimulation of the sympathetic.

CHAPTER XII

BLOOD-VESSELS. LYMPHATICS

The Structure of the Blood-vessels.—The walls of the arteries and veins consist of three coats. These are (1) a tough outer coat of fibrous tissue, (2) the middle muscular and elastic coat and (3) a thin internal lining of endothelium. The walls of the arteries are tough, strong and elastic, while those of veins are thinner and weaker. The larger arteries have more marked muscular coat, while in the veins the middle coat contains a much less proportion of muscular and elastic tissue. On account of this deficiency of elastic tissue the veins collapse when cut while the arteries remain open.

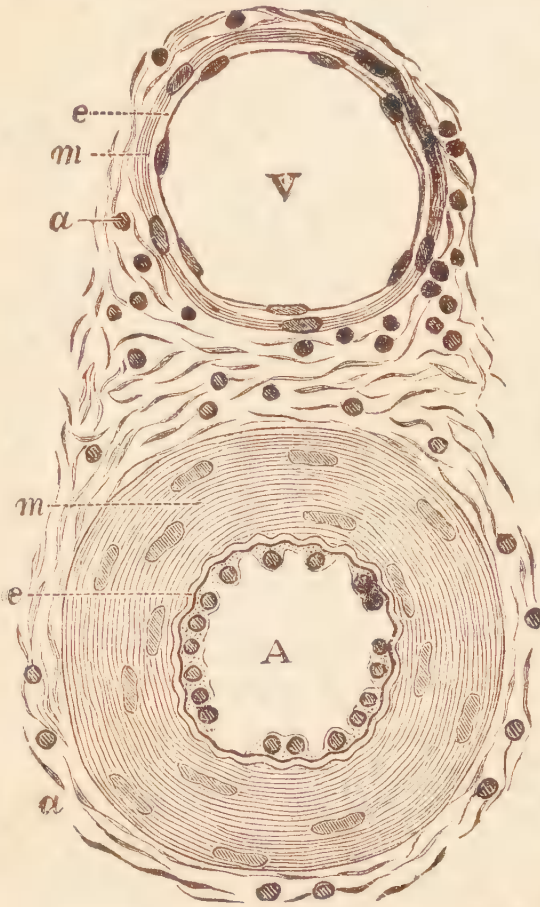


Fig. 55.—Section of Small Artery and accompanying vein (magnified).

(From Gray's 'Anatomy.'
By permission.)

A, artery; V, vein; a, fibrous tissue showing nuclei of cells; m, muscular and elastic coat; e, inner endothelial lining.

Most veins are provided with pocket-shaped valves in their interior which are usually arranged in pairs, with the cavities of the pockets turned towards the heart. They can come together and prevent the backward flow of blood. Thus they only allow the passage of blood towards the heart. The presence of these valves can be easily demonstrated by pressing the arm

firmly towards the hand, when little swellings appear in the course of the veins at the site of the valves.

In the smallest arteries the middle and the outer coats gradually disappear and in the capillaries only the inner

endothelial lining is left. The capillaries are generally arranged in the form of a network. Their walls are exceedingly thin and easily allow the passage of fluid or diffusion of gases, and therefore the changes that the blood undergoes during its circulation chiefly occur while passing through these vessels.

The Nervous Control of Blood-vessels.—It often happens that a particular part of the body needs more blood than another. Thus when the food is being digested in the stomach, more blood is needed by the stomach than when



Fig. 56.—Vein cut open to show pairs of semi-lunar valves.

(From Thornton's 'Elementary Practical Physiology.' By permission.)

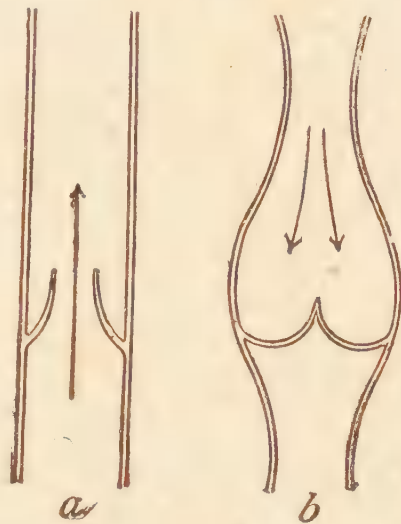


Fig. 57.—Diagrammatic section of veins to show action of valves.

a, valves open ;
b, valves closed.

the latter is at rest. It may be taken as a general rule that more blood goes to the parts when they are active than at rest. This is achieved by the blood-vessels going to the part becoming wider. The muscular coats of the smaller arteries are supplied by nerves called **vaso-motor nerves** which have the power of making the blood-vessels wider or narrower. These nerves are under the control of a group of cells in the medulla oblongata and nervous impulses are constantly passing to the small arteries and keeping them in a state of moderate contraction. The part of the medulla is stimulated or depressed not only by the state of the

blood circulating around it but also by the nervous influences from other parts of the brain. Thus blushing is often due to dilatation of vessels of the skin of the face from some emotion. The centre in the medulla is so acted that the nervous impulses passing by the vaso-motor nerves to the arteries of the face, which ordinarily keep them in a state of moderate contraction, become relaxed, and more blood passes into the capillaries of the face. If as in fright, nervous impulses that contract the smaller arteries are increased, less blood goes to the face, and pallor is the result. Again dilatation of face may come about from exposure to heat or even rubbing the face. In these cases the nervous impulses are said to be 'reflex' in type, as stimuli proceed from the face to the medulla and the nervous impulses are sent back through the vaso-motor nerves.

The Lymphatic System.—The lymphatic system consists of lymphatic vessels and lymphatic glands, through which passes a watery fluid called the **lymph**. Lymph is the colourless liquid which exudes through the walls of the capillaries as the blood passes through them, and consists of water, proteins, carbohydrates and the salts of the blood dissolved in it. It also contains some white corpuscles that have passed out of the blood capillaries, but no red cells. It comes in direct contact with the cells of the tissues and thus serves to bring nourishment to them, the tissues selecting the particular substances they require. It also washes away the waste products resulting from the activity of the tissues. In addition to the food material the lymph carries the oxygen from the blood to the tissues and removes the carbon dioxide produced in them. It is important to remember that the blood in no way comes in direct contact with the cells, but only indirectly through the lymph. The lymph is in reality the life-giving fluid for the tissues.

After nourishing the tissues and removing the waste products the greater portion of the lymph flows back into the blood capillaries, but a small amount which is not thus absorbed flows into minute spaces which are the beginnings of **lymphatic capillaries**.

The lymphatic capillaries unite with similar vessels coming from neighbouring groups of cells and ultimately form



Fig. 58. — Diagram of Lymphatic System, showing vessels and glands (white).
(From Marshall's 'Physiology.' By permission.)

a, thoracic duct opening on the left at the junction of two veins at the root of the neck; *i*, portion of intestine with lacteals passing from it.

larger **lymphatic vessels** which on their course pass through enlargements called **lymphatic glands**. The lymphatic glands act as filters of lymph, retaining and killing any harmful matter such as disease-producing germs. That is why in the case of dirty wounds, ulcers, etc., lymphatic glands get enlarged and swollen and prevent the infective material from getting beyond them. They also produce lymphocytes, which is one variety of white cells in the blood. They are therefore called the police stations of the body, as they not only arrest and destroy foreign material, but also produce lymphocytes which will act as guards when circulating in the blood. The lymphatics after passing through the glands unite with similar other lymphatics and ultimately form two large lymph channels, the **thoracic duct** which opens into the left subclavian vein and **right lymphatic duct** which opens into the venous system at a corresponding place on the right side.

The lymphatic channels on the whole are similar in structure to the veins, but have thin walls which readily collapse when empty, and so are difficult to find. They are provided all through with semi-lunar valves, and the flow of lymph is aided by the muscular movements of the part through which the lymphatics are running.

The lymphatic vessels coming from the digestive tract are called **lacteals** (Lat., *lactis*, milk) because after a meal their contents are milky in colour. It is due to the fact that besides absorbing tissue lymph they absorb, as already stated in the chapter on Digestion, the emulsified fat. This white milky fluid consisting mostly of emulsified fat is called **Chyle**.

CHAPTER XIII

RESPIRATION

Need for Respiration.—In the first chapter we have already learnt that every action in the body means a chemical change in some cells. When a muscle contracts, a gland secretes or the brain thinks, some chemical change is taking place in the cells of the tissue concerned. We have also seen that the chemical change is a process of oxidation, the oxygen carried by the blood to all parts of the body, uniting with the compound substances and breaking them down. As the result of these katabolic activities a number of substances are produced which are of no use in the body and must be got rid of. As carbon is an element present in all tissues, one of the most abundant of waste products in the body is carbon dioxide. In any part of the body, while the blood is passing through the capillaries, oxygen is given up and passes out through the thin walls of the capillaries, and carbon dioxide passes in and is added to the blood thus rendering the latter venous and changing the bright scarlet colour to a dark purple. The venous blood from all parts of the body is returned to the right auricle and passing down into the right ventricle, is sent out to the lungs, in the capillaries of which is effected a reverse exchange of gases, carbon dioxide and water vapour being thrown out and fresh supply of oxygen taken in. For this purpose fresh air enters the lungs and fouled air expelled with every breath. Respiration or breathing is thus the process by which fresh supply of oxygen is obtained and carbon dioxide removed.

Differences between Pure and Respired Air.—The air is a mixture of several gases. Pure atmospheric air contains nearly 79 per cent of nitrogen and about 21 per cent of oxygen, together with a mere trace of carbon dioxide and a variable quantity of water vapour. As the blood passing through the capillaries of the lungs throws off certain waste matters and takes in oxygen there are considerable

differences between the air we breathe in and the air we breathe out. The expired air contains 16 to 17 per cent of oxygen and 4 to 5 per cent of carbon dioxide. The percentage composition by volume of inspired air and expired air is given in the following table :—

	Inspired air	Expired air.
Nitrogen	... 79·00	79·00
Oxygen	... 20·96	16·50
Carbon dioxide	... ·04	4·50
Water vapour	... Variable amounts. Saturated.	

It will thus be seen that the changes consist in a loss of nearly five volumes of oxygen, an increase of about an equal volume of carbon dioxide, and an increase of water vapour. The expired air is usually warmer than the inspired air, as it has nearly the same temperature as that of the body. Expired air also contains minute quantities of organic matter thrown out by the body.

The presence of carbon dioxide in the expired air may be shown by breathing into clear lime-water. Take a small quantity of lime-water in a small tumbler or cup and breathe into it through a glass tube, the end of which is dipping under lime-water. Make each expiration as long as you can. The water gradually becomes milky. This is due to the union of carbon dioxide with the lime to form calcium carbonate or chalk. The presence of water vapour may be shown by breathing on a slate or a cold glass plate, when the latter is seen to be covered with moisture. That the expired air is warm is easily borne out by our experience on a cold day of blowing our hands to warm them.

Organs of Respiration. In order to reach the lungs the air passes through the nose or mouth into the pharynx and thence into the larynx which is situated at the top of the wind-pipe or trachea. In passing through the nose, the air becomes warmed, as well as freed from particles of dust by hairs situated inside the nostrils. It is important therefore to breathe through the nose and not through the mouth. The pharynx communicates with the larynx and trachea and also with the posterior tube, the oesophagus which leads to the stomach. The opening into the larynx (glottis) is guarded by a cartilaginous lid called epiglottis. Ordinarily the epiglottis stands erect, permitting the air to

pass freely into the larynx, but during swallowing, it is pulled upwards and backwards thus serving to close the entrance and preventing food and drink from passing into the larynx (Fig. 38).

The **trachea** or wind-pipe is about five inches in length and is made stiff by incomplete rings of cartilage contained in its walls. But for these rings, the trachea would collapse with the slightest pressure and cause suffocation.

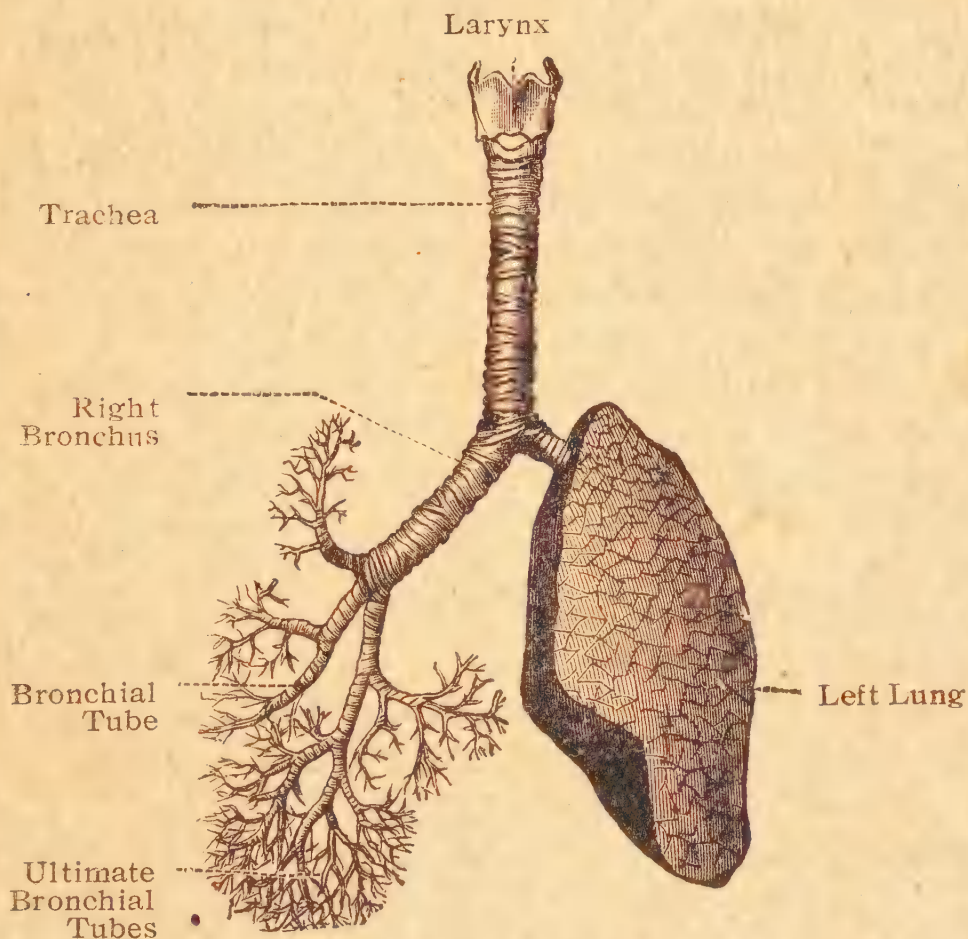


Fig. 59.—Larynx, Trachea and the Lungs.

(From Miller's 'Physiology.' W. Collins, Sons & Co., Ltd.
By permission.)

One lung has been dissected to show the air tubes.

The tube is completed behind by a membrane which is capable of yielding when the neighbouring tube, the oesophagus is stretched by some food passing through it. The trachea runs down the neck, in front of the oesophagus and passes into the thorax. Here it divides into two branches known as the right and the left bronchi. Each bronchus enters a lung, and within it divides again and again into smaller and smaller bronchial tubes. The

structure of the bronchi and bronchial tubes is similar to that of the trachea, but the smallest bronchial tubes have no cartilage in their walls. The trachea and the bronchial tubes are lined with a mucous membrane which is kept moist by a secretion of some of its cells. The inner layer of cells composing this membrane are provided with fine hair-like processes called cilia. The cilia are constantly working driving any dust that may reach the air passages, up into the throat, from where it may be coughed out.

The two **lungs** are greyish-looking, spongy and elastic organs, which fill during life the cavity of the thorax on each side of the space occupied by the heart. In each lung

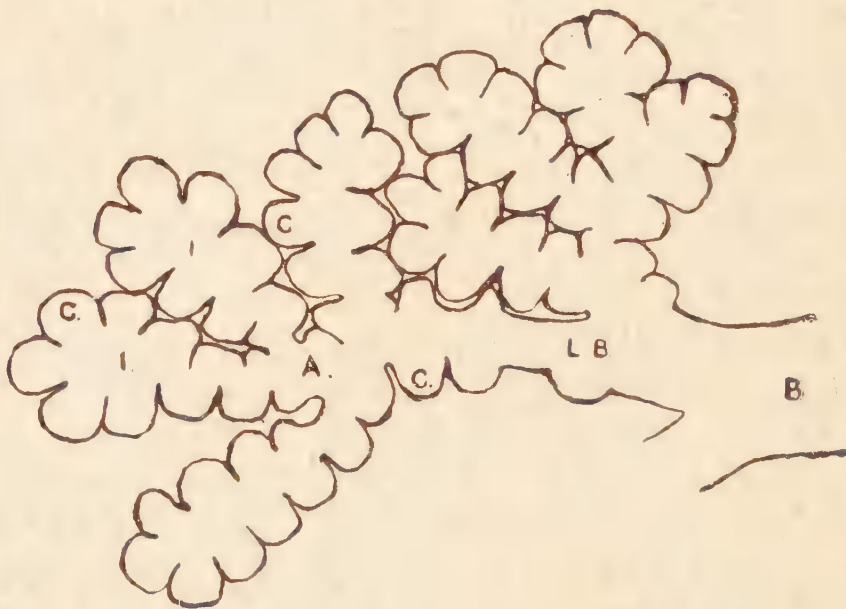


Fig. 60.—A bronchial tube ending in sacculated infundibula.

(From Quain's 'Anatomy.' By permission.)

B, terminal bronchiole ; 1, infundibulum ; C, air-sacs or alveoli.

the bronchial tubes divide and subdivide to such an extent that the smallest of them can be seen only with the aid of a microscope. Every one of these smallest or ultimate bronchial tubes ends in a bunch of swollen sacs called infundibula. Each of these sacs has numerous small pouches or recesses known as air-sacs or alveoli. The lung thus consists of millions of tiny air-sacs packed together, each air-sac communicating through the bronchial tubes with the outside air. These infundibula look like bunches of grapes, each air-sac corresponding to one grape in the bunch. By this arrangement of innumerable minute bronchial tubes opening into a still larger number of air-sacs, the surface which comes in contact with the air is

vast, being estimated at no less than about fifty-five times as great as the entire outer surface of the body. The walls of these air-sacs are exceedingly thin, being composed of a fine layer of flattened cells. It is in this thin connective tissue that blood-capillaries derived from the repeated branching of pulmonary artery are spread out. The venous blood circulating in these capillaries is thus separated from the fresh air in the air-sacs by the exceedingly thin wall of the capillary and equally thin wall of the air sac. When gases are separated by such thin partitions they can readily mix with one another or **diffuse**. In this case owing to the powerful affinity of hæmoglobin of the red blood corpuscles for oxygen, some of that gas passes into the capillaries and some carbon dioxide passes from the blood into the air-sacs.

The blood in the capillaries thus becomes oxygenated and changed from dark venous to bright arterial. These capillaries unite to form small veins, which uniting with other similar veins form the pulmonary veins that take the oxygenated blood to the left auricle of the heart.

The greater part of the lung is formed of the infundibula and alveoli filled with air. The thorax being an air-tight cavity keeps off the pressure of the outside air, but the same atmospheric pressure is exerted through the air in the bronchial tubes and alveoli and stretches the lungs so as to completely fill the space in the thorax. In life the lungs are naturally in a distended condition undergoing a change in their volume with the change in size of the cavity of the thorax due to movements caused by the contraction and relaxation of certain muscles. If an opening is made into the thorax as in dissection, atmospheric pressure is exerted on the outside of the lungs also and they immediately collapse to about one-third their natural size. Even then the bronchial tubes and air-sacs do not close up completely. A piece of lung will still contain some air, and float if thrown into water.

Each lung is invested by a thin membrane, which covers it as far as the root of the lung and is then reflected over the inner surface of the chest wall and over the diaphragm. This membrane known as the **pleura** is thus a double bag, the two layers of which are ordinarily moistened by a little fluid and glide over one another quite smoothly.

The Movements of Respiration.—It is obvious that the air in the lungs must be constantly renewed or it would lose all oxygen and become loaded with carbon dioxide. This is done by regular movements of the diaphragm and the chest wall.

We have learnt above that the cavity of the thorax is an air-tight chamber, which communicates with the outside only through the trachea, and that the pressure of the air in the passages keeps the lungs in a distended condition. When the cavity is enlarged, the pressure of the air would

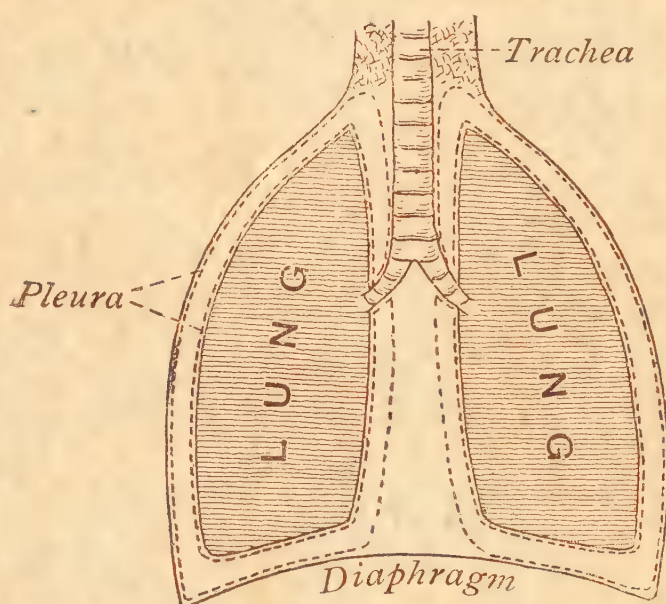


Fig. 61.—Diagram of the Thorax showing the Lungs, Pleura and Diaphragm.

(From Thornton's 'Elementary Practical Physiology.' By permission.)

Dotted lines represent the two layers of pleura, which are really in contact with one another.

cause the lungs to expand to a greater extent to fill the extra space, and on the contraction of the cavity the lungs would also contract to force out the extra quantity of air taken in. These two movements are performed regularly about seventeen times per minute.

The **diaphragm** is a muscular partition between the thorax and the abdomen. It is like a dome with its convexity towards the thorax and the concavity towards the abdomen. Its central part is a sheet of tendon from which muscular fibres spread outwards to be attached

to the sternum, costal cartilages, ribs and behind by two strong bands to the lumbar vertebræ.

When the muscular fibres of the diaphragm contract, it becomes flatter and less dome shaped. The cavity of the thorax is enlarged from top to bottom. This descent of the diaphragm presses upon the organs in the abdomen and causes the abdomen to swell out. When the diaphragm relaxes and consequently rises up again, the cavity of the thorax is diminished. These two movements of the diaphragm are the principal factor in ordinary quiet breathing.

The cavity of the thorax is enlarged in another way also. The walls of the thorax are formed by the ribs, which articulate with the vertebræ behind and the sternum in front. The spaces between the ribs are occupied by strong muscles called the **intercostal muscles**. There are two layers of these muscles, the outer being called the external

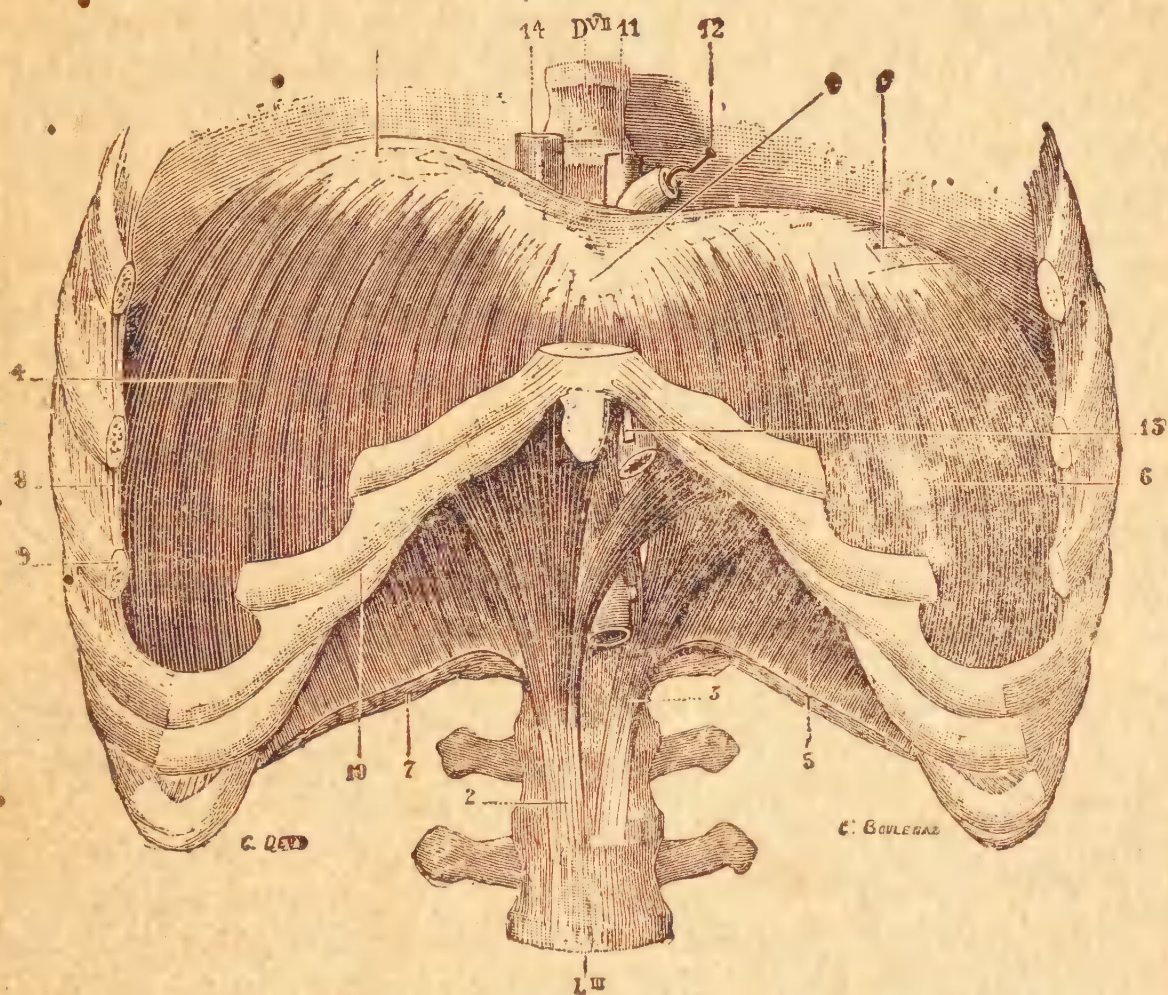


Fig. 62.—View of Diaphragm, with its convex upper surface in front.

(From Testut's 'Anatomy.' By permission.)

1, 1', and 1'', the central tendon; 2 and 3, pillars of the diaphragm inserted into the lumbar vertebræ; 4 and 6, muscular sheet passing to ribs; 5, hinder lower surface; 9, section of a rib; 10, costal cartilage; 11, aorta; 12, oesophagus; 14, lower vena cava; D VII, seventh dorsal vertebra; L III, third lumbar vertebra.

intercostal muscles and the inner the internal intercostal muscles. When the external intercostal muscles contract, they pull up the ribs. As the slanting ribs are pulled up, they push the sternum forwards and so the cavity of the thorax is enlarged from front to back. The elevation of the ribs is accompanied by a slight opening out of the angle which the bone makes with its cartilage, and thus

there is an increase in the width of the cavity from side to side also.

The enlargement by means of the side walls takes place at the same time as the flattening of the diaphragm, so the cavity of the thorax is simultaneously enlarged in three diameters, viz. from side to side, from before backwards,

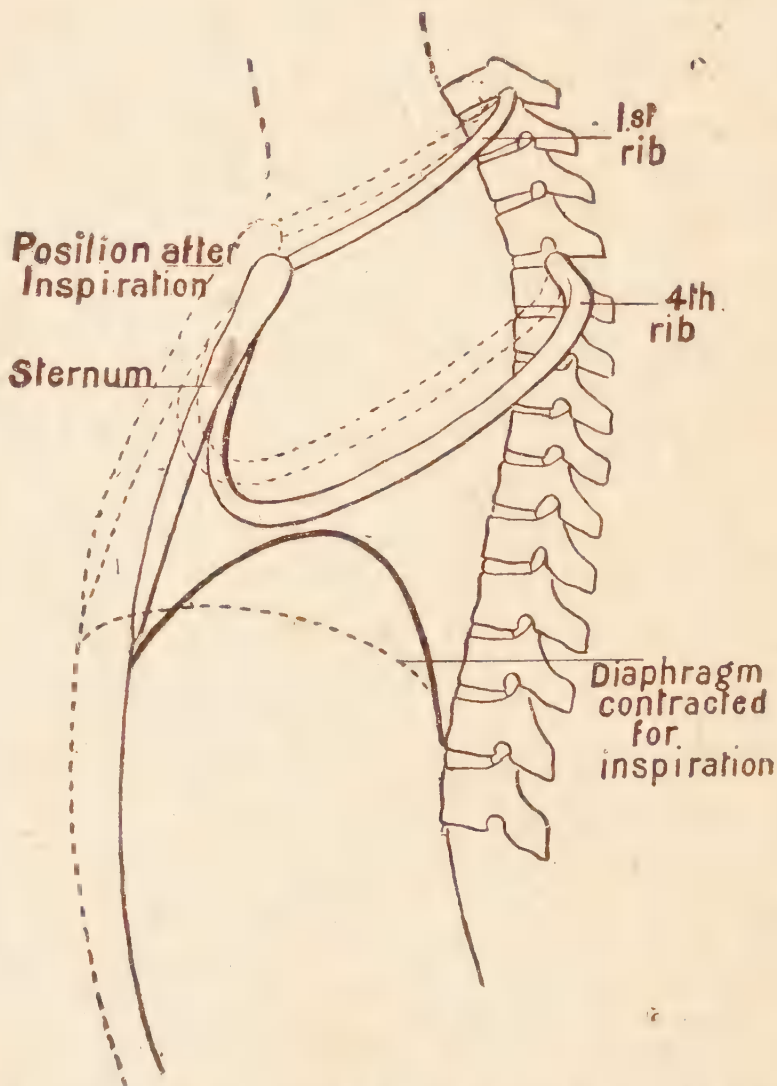


Fig. 63.—Movement of Ribs, Sternum and Diaphragm.

(From Lyster's 'First Stage Hygiene.' University Tutorial Press.
By permission.)

The dotted lines show the position occupied by the sternum, ribs, diaphragm and the abdominal wall at the end of a full inspiration.

and from top to bottom. As a result of this increase in the volume of the thorax air rushes down the air-passages to distend the lungs and **inspiration** is the result. Immediately after the inspiration, muscles causing the movements of inspiration cease to contract. The diaphragm relaxes and becomes dome-shaped and the ribs and sternum fall back to

their former position. By these combined movements, the chest cavity becomes smaller and the air is forced out of the lungs, the elasticity of the latter also aiding in the process. This turning out of the air constitutes an **expiration**.

Inspiration plus expiration constitutes respiration. A healthy man at rest breathes sixteen or seventeen times a minute; children breathe about twenty-five times and an infant as much as forty times a minute. In boys and men the diaphragm plays a more important part in respiration, with the result that when they draw a breath the chest moves very little but the front of the abdomen bulges owing to the diaphragm pressing on the liver and other abdominal organs. In women the movement of the ribs and sternum is more conspicuous.

Quantity of Air.—At each inspiration a grown-up person takes in about thirty cubic inches of air and breathes out an equal quantity of air in the succeeding expiration. At the end of an ordinary respiration, there are about 200 cubic inches of air in the lungs. This air is only gradually renewed by mixing with the air which is coming in and going out and thus sudden changes of temperature in the lungs are avoided.

At the end of an ordinary respiration an extra 100 cubic inches of air can be forced into the lungs by taking a deep breath. Similarly at the end of ordinary expiration an extra 100 cubic inches can be driven out by forced expiration.

Thus we find that in ordinary breathing we do not expand our lungs to their full extent, nor do we empty them completely. The more completely the air in the lungs is changed, the better will be the resulting ventilation of the lungs. It is good therefore, to cultivate the habit of deep breathing for a few minutes every morning and evening.

Effect of Exercise on Respiration.—The breathing becomes more rapid during exertion of any kind. When running, one pants for breath. This is due to the fact that muscles are working hard, using up more oxygen and producing more carbon dioxide. The increased amount of carbon dioxide circulating in the blood so affects the respiratory centre in the brain, that messages are sent out to various muscles concerned to cause more rapid movements of respiration. These rapid movements not only serve to oxygenate the blood, but also help to accelerate the pulmonary

circulation. Not only more air but more blood is drawn into the expanding lungs during inspiration, and driven out of them during expiration.

Nervous Control.—The respiratory movements are going on without any attention on our part. Nervous impulses are constantly passing through certain nerves to the diaphragm and the intercostal muscles. These impulses are proceeding from a small area called the **respiratory centre** situated in the part of the brain called the medulla. The respiratory centre is receiving impulses through a nerve distributed in the substance of the lung, and normally it is in response to these in-going impulses that out-going impulses are being sent to the respiratory muscles. The brain can however influence the respiratory centre to suspend or modify its working. Thus, we can, when we will, suspend breathing or breathe more rapidly, though only for a minute or two.

CHAPTER XIV

THE KIDNEYS AND THE EXCRETION OF URINE

Metabolism.—We have learnt that during the various activities constituting life, some cells of the tissues die and disintegrate (**katabolism**), while new cells are formed and replace the old ones (**anabolism**). The vital processes of katabolism and anabolism are going on side by side and the sum total of the activities of the body is described as **metabolism**.

During the various katabolic activities, certain waste products, especially oxidation products of carbon (viz. CO_2), hydrogen (viz. H_2O), and a nitrogen containing compound known as Urea are formed, which are ultimately washed by the lymph into the venous circulation. These must be continuously removed from the system, otherwise they would cause poisoning and death. They are normally removed from the body by the lungs, the kidneys and the skin. To a very small extent the liver also helps in removing waste products, in the form of bile. The organs that remove the waste products from the body are known as **Excretory Organs**. We have in a previous chapter described the lungs and the mechanism by which they excrete carbon dioxide and water vapour. We shall here consider the work of the kidneys and in the next chapter that of the skin.

The Kidneys.—The **kidneys** are two in number, situated one on each side of the vertebral column and in front of the last ribs. They are thus situated fairly high up in the body. They are dark-brown in colour and are embeded in a mass of fat. On the upper end of each kidney rests like a cap, a small ductless gland called the **supra-renal body**, the function of which has been referred to in a previous chapter. The kidneys have a characteristic bean-shaped appearance, the outer edge being convex, and the inner concave, the latter being marked by a depression called the **hilum** or **hilus**. Here the blood-vessels of the kidney, i.e., an artery and a vein, enter and leave the organ and the

ureter or the duct of the kidney comes out. The ureters pass downwards to open into the **bladder**. The bladder is a muscular bag lying in the pelvis, in which the urine is collected. The urine is constantly being poured into the bladder by the ureters and when it gets filled, the bag

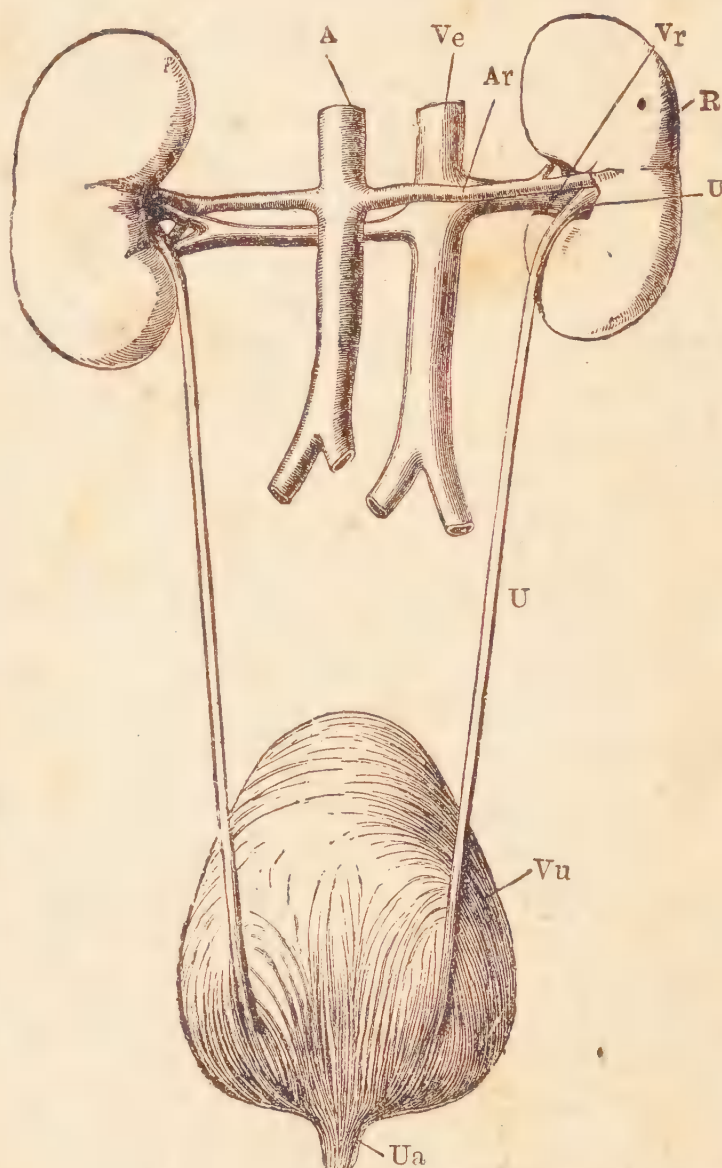


Fig. 64.—The Urinary System viewed from behind.

(From Furneaux's 'Human Physiology.' By permission.)

R, right kidney; U, ureter; A, aorta; Ar, renal artery; Ve, inferior vena cava; Vr, renal vein; Vu, bladder; Ua, commencement of urethra.

contracts and the urine is passed through the **urethra**, a small tube opening to the outside of the body. The urethra is kept closed by a ring of muscular fibres, which relaxes only when urine is to be passed out.

The urine is composed of two nitrogen containing organic compounds, *urea* and *uric acid*, and certain inorganic salts dissolved in a large quantity of water.

Structure of kidney.—The human kidney is very much like that of a goat or sheep, and specimens of the latter may be obtained from a butcher for purposes of study. If a longitudinal section of the kidney be made by cutting with a long knife from the outer convex surface to the hilus, it will be seen that the ureter widens out into a cavity with a number of short wide prolongations. The large cavity is called the **pelvis** of the ureter and its branches **calyces**. In other words the various calyces unite to form the pelvis.

The cut surface of the solid portion of the kidney consists of an outer dark coloured and granular **cortical portion** or the **cortex** and an inner paler portion called the **medullary substance** or the **medulla** of the kidney. The medulla is streaked in appearance and is made up of numerous fine tubules arranged in conical portions called **pyramids**. The base of each pyramid lies towards the cortex, while its pointed end projects into one of the cup-like branches of the pelvis. Bands of cortical substance are also seen to run inwards between the pyramids. By squeezing a pyramid some urine may be seen to flow from the tubules of which it is composed, into the pelvis.

Blood-vessels of the Kidney.—If you examine the hilum of the kidney you will find that in addition to the ureter, the **renal artery** enters the kidney carrying blood to it for purification (i.e., separation of waste nitrogenous substances), while the **renal vein** comes out of it bringing the blood back to the general circulation. In the substance of the kidney the small branches of the renal artery and the renal vein are united together by minute renal capillaries which surround the kidney tubules. The renal vein contains the purest blood in the body as the waste products have been removed through its passage in the kidney.

Microscopic Structure of the Kidney.—Under the microscope, a thin section of the kidney is seen to be composed of numerous long coiling tubules surrounded by a fine network of blood capillaries, the whole bound together by connective tissue. Every tubule begins in the cortex in

a small cup-like expansion called the **Malpighian body**¹ and after following a somewhat tortuous course eventually

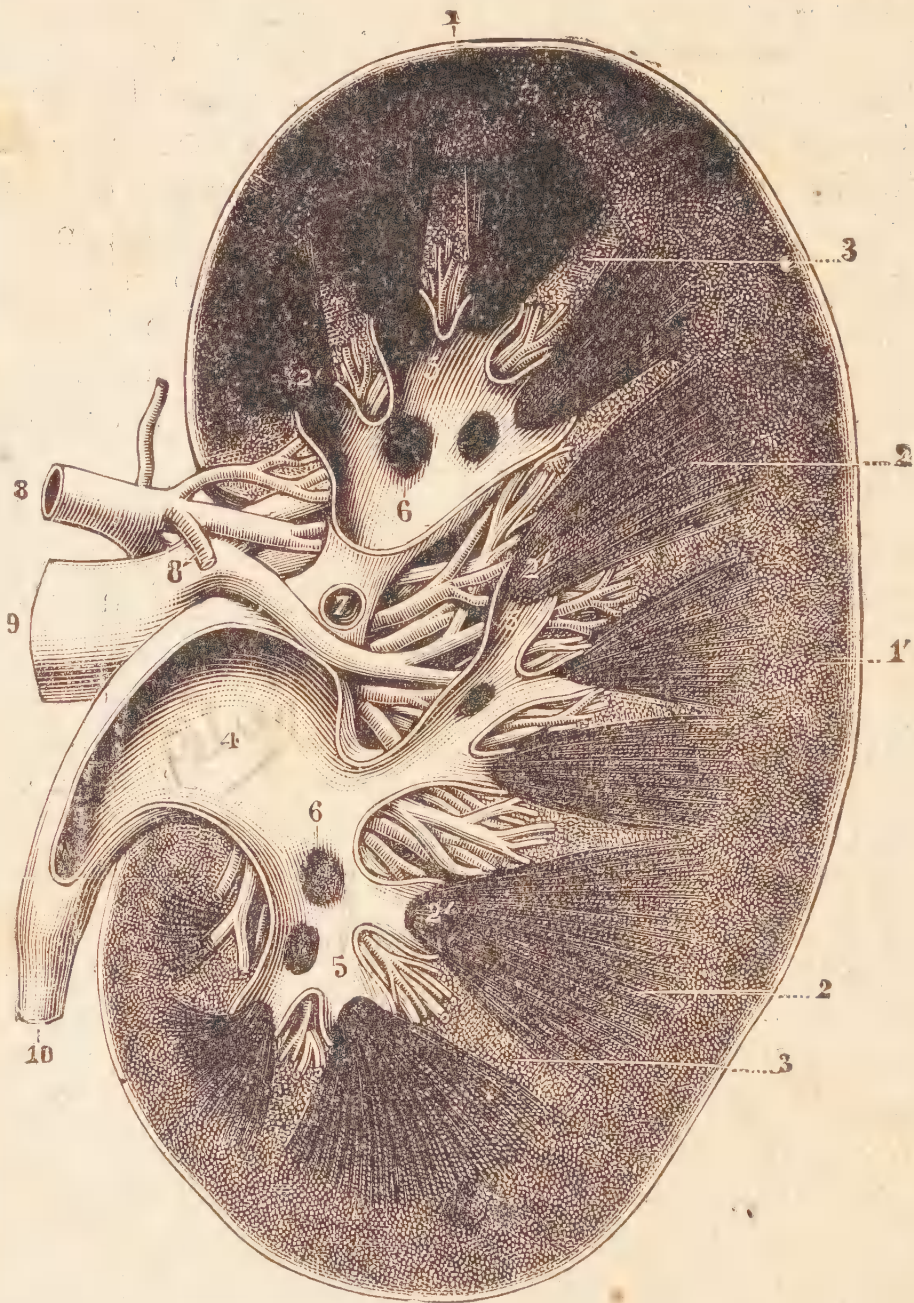


Fig. 65.—Longitudinal section of kidney.

(From Thornton's 'Elementary Practical Physiology.' By permission.)

1, capsule ; 1' and 3, cortex ; 2 and 2', pyramids of medullary substance ; 4, pelvis or dilated end of ureter with (5) calyces of the pelvis into which pyramids project ; 8 and 8', renal artery ; 9, renal vein ; 10, ureter.

joins one of the larger tubes which run straight through a pyramid and open into the funnel-shaped pelvis. The

¹ Named after Malpighi, an Italian anatomist of the seventeenth century.

small branches of the renal artery run along the straight tubes in the medulla, and each gives a small branch to the malpighian body, which breaks up in its interior into a rounded cluster of blood capillaries called a **glomerulus**. The blood is then collected by a small vein which is of a smaller diameter than the ingoing artery. It again breaks up into small capillaries which surround the uriniferous tubules and ultimately unite into veins which running through the medullary portion open into the renal vein.

Function of the Kidney.—The function of the kidney is to purify the blood by removing the waste products of metabolic activities. It acts as a filter removing the nitrogenous compounds called urea and uric acid, along with the excess of chlorides, sulphates and phosphates of sodium and potassium. These organic and inorganic substances are held in solution in a large quantity of water, also separated from the blood, and the fluid is called *urine*. Urine is a pale yellow liquid with a specific gravity of about 1020. About 50 ounces of urine are excreted in twenty-four hours, the amount varying with the quantity of water taken and the amount given off as perspiration. Normally no sugar or albumen is present in the urine and if any is detected by chemical tests it is a sign of disease.

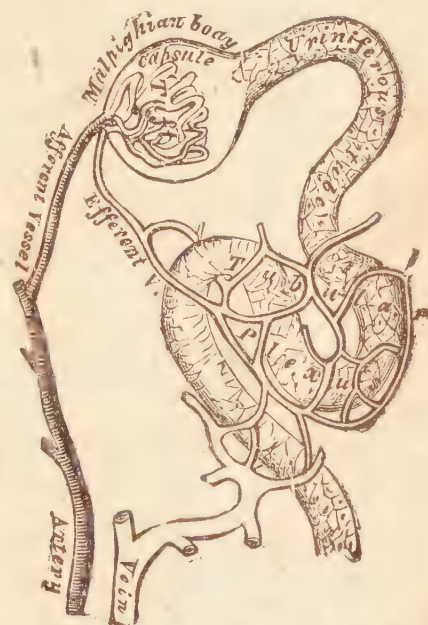


Fig. 66.—A Kidney tubule and its blood-supply (highly magnified).

(From Gray's 'Anatomy.'
By permission.)

The separation of urine from the blood occurs in the glomeruli. Large quantities of plasma are filtered off when the blood is flowing under pressure through the glomeruli, but substances which are useful to the body such as inorganic salts together with certain quantity of water are reabsorbed into the blood as the urine passes through the tubules. It must be remembered however, that kidneys only act as filters and that the urea and uric

acid are not prepared by the kidneys but by the liver and muscles.

The secretion of the urine by the kidneys is a continuous process and it passes drop by drop into the bladder from which it is passed out at intervals. If by any cause such as disease of the kidneys, the kidneys cease to function and are unable to remove the waste products from the blood, the body gets poisoned and the person dies.

CHAPTER XV

THE SKIN AND THE EXCRETION OF SWEAT. BODILY HEAT

The Skin.—The skin covers the whole of the body and protects the underlying muscles. It is also an organ for the excretion of waste materials, regulation of the temperature of the body, and for the sensation of touch and temperature.

The skin consists of two layers, the superficial layer or the **epidermis** and the deeper layer or the **dermis**.

The thickness of the epidermis varies in different portions of the body, being about $\frac{1}{20}$ of an inch over the soles of the feet and about $\frac{1}{200}$ of an inch over the face. The epidermis or the superficial layer is hard, composed of many layers of epithelial cells the most superficial of which are scale like and almost horny in nature. They are for the protection of the deeper cells and are continually being worn off and replaced by the deeper ones. The deeper part of the epidermis is called the **Malpighian layer**. The lowest cells of the Malpighian layer contain granules of pigment, which gives the skin its special colour, whether dark or brown or fair. In the Europeans the amount of pigment is generally small, and it is greatest in the skin of the negro. The pigment is a gift of nature, better adapting the coloured races to live in tropical climes.

The epidermis is devoid of blood-vessels and the cells of its deeper layer are nourished by the lymph which oozes out from the vessels in the dermis. There are only a very few fine nerve fibres passing into them and it is for this reason that we do not feel pain when the epidermis alone is injured.

When seen under a magnifying lens, the surface of the epidermis is seen to be studded with small pores, which are the openings of the ducts of the sweat-glands which secrete perspiration.

The various cavities of the body are lined with a soft pink membrane called the **mucous membrane** which is

continuous with the skin at the margins of the lips, eyelids, etc. Unlike the epidermis, mucous membrane readily absorbs substances in solution, and that is why medicines which have no effect when rubbed on the intact skin, produce rapid effect when dropped into the eyes or put under the tongue.



Fig. 67.—Vertical section of the skin, as seen under a microscope.

(From Thornton's '*Elementary Practical Physiology.*'
By permission.)

1, horny layer of epidermis ; 2, Malpighian layer of epidermis ; 3, dermis ; 4, subcutaneous tissue ; 5, blood-vessels ; 6, touch corpuscle in a papilla of dermis ; 7, sweat-glands with tubes passing to the surface ; 8, coiled part of the duct ; 9, group of the fat-cells ; 10, cut end of a blood-vessel.

The **Dermis** or true skin lies just beneath the Malpighian layer and consists of connective tissue which is compact in its upper part and looser in the deeper portion where it also contains a small amount of fat. Beneath this again is loose sub-cutaneous tissue which contains much fat and serves to fill up the irregularities in the underlying parts and thus give to the body a plump

appearance. The looseness of the sub-cutaneous tissue enables us to pinch up the skin, while the large amount of fat serves not only as a store of energy but also keeps the body warm by preventing loss of heat, as fat is a bad conductor of heat. The dermis is well supplied with nerves, blood-vessels and lymphatics. The upper surface of the dermis shows distinct finger-like projections called papillæ, arranged in close set parallel rows. Each papilla contains a bunch of blood capillaries and an oval nerve ending called a touch-corpuscle. In most sensitive parts of the skin these papillæ are very abundant and the epidermis lying over them is thin.

Skin glands.—The skin contains two kinds of glands (1) the sebaceous glands which secrete an oily fluid and are found in connection with the hair and (2) the sweat-glands which produce perspiration. We have already mentioned the pores in the skin as the openings of the ducts of sweat glands. Each sweat-gland is a small coiled-up tube in the sub-cutaneous tissue surrounded by numerous capillaries. As the blood circulates through these vessels, the cells of the gland secrete sweat and pass it along to the surface through the long spiral duct. The sweat contains water, sodium chloride, and urea. It is poured out on the surface of the skin and is carried off by evaporation unless it is very large in amount when it collects in drops. When the sweat evaporates into the air as soon as it comes to the surface, it is called insensible perspiration, for we are not conscious of it. But when it collects on the skin it is

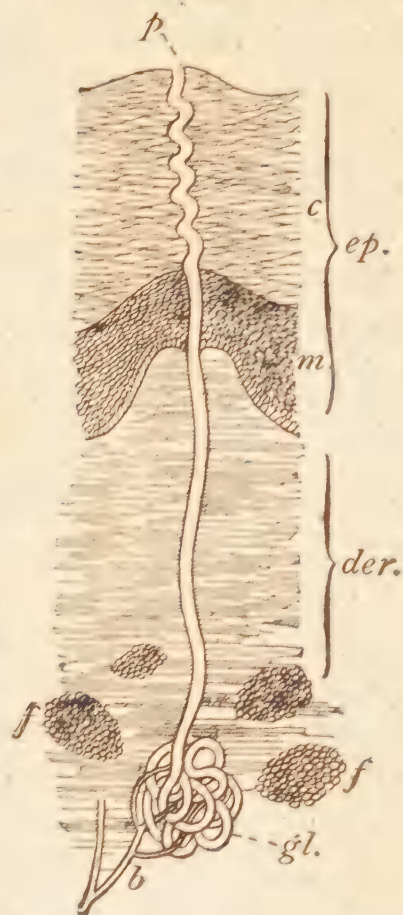


Fig. 68.—A sweat-gland with its duct, highly magnified.

(From Thornton's 'Elementary Practical Physiology.' By permission.)

gl., sweat-gland;
b, capillaries passing around and among its coils; p, pore, or opening of the duct; ep., epidermis, with c, horny layer, and m, Malpighian layer; der., dermis; f, fat cells.

called visible perspiration. The amount of sweat secreted varies with the season, amount of exercise taken, etc.

One of the uses of sweat is to keep the body at the same temperature. Thus during the hot weather or after hard physical exertion when there is great amount of heat produced in the body, the skin is cooled by the evaporation of an increased amount of perspiration. During the evaporation of any liquid heat is taken up from the body with which the liquid is in contact, thus lowering its temperature. Thus by the evaporation of sweat the skin is cooled. The increased production of sweat in the hot weather or after exercise is due to the dilation of blood capillaries in the skin brought about by the action of vasodilator nerves and the consequent increased flow of blood to the skin. In addition the sweat glands are also directly stimulated to increased activity through the secretory nerves.

Nails and Hairs.—These are only outgrowths of epidermis and consist of modified epidermal cells transformed into a horny substance. The dermis at the root of the nail is very vascular and cells of the epidermis covering it multiply very rapidly. The cells so formed become compressed and horny and push forward, thus increasing the nail in length.

The hairs are also produced from epidermis. Each hair consist of a shaft and a root and is provided with a small gland, called sebaceous gland which secretes an oily substance to lubricate the hair.

The **shaft** of the hair consist of a loose inner cellular **medullary portion** covered by the flattened overlapping scale like **cortex** in which the pigment granules are deposited. It does not contain any nerves or blood-vessels. The **root** of the hair is fixed in a pit in the dermis, formed as an ingrowth of the epidermis and called a **hair-follicle**. At the bottom of the follicle there is a small dermal papilla which is supplied by a blood capillary and a small nerve, and it is from this point that the growth of a hair takes place.

The **sebaceous glands** are little sacs situated in the dermis and their ducts open into the hair follicles. They secrete an oily substance which lubricates the hair and gives them a glossy feel.

Every hair has got a small involuntary muscle attached

to its follicle, which by its contraction makes the hair more erect or as popularly described, 'stand on end'.

Cleanliness.—It is obvious from what we have described above that if the skin is not properly cleansed a cake of dirt consisting of cast off epidermal cells, dust, oily substance and sweat is liable to form over it. This not only provides a suitable medium for the growth of germs and give rise to skin diseases, but also interferes with the proper discharge of functions of the skin, throwing an extra burden on the kidneys. If the kidneys are not able to perform the heavier work thus thrown on them, they get diseased. Again, if from any cause evaporation of the sweat is interfered with, the temperature of the body is liable to rise. It is therefore necessary to look upon the skin as an important organ of the body and keep it in a clean and healthy condition.

Maintenance of Bodily Heat.

—The chief tissues which produce heat are those in which active chemical changes are going on, such as the *muscles*, the *secretory glands*, and the *nerve centres*. These

chemical changes are

chiefly of the nature of oxidation, producing carbon dioxide and generating heat. It is therefore obvious that the more active the muscles, glands or the brain, the greater the oxidation and consequent heat production. As already stated the various food stuffs differ in the amount of heat which they produce when oxidized in the body. Thus weight for weight, oils and fats produce twice as much heat as proteins, while the carbohydrates come somewhere between the two. That is why in winter or when on active training we eat more of fats and carbohydrates than in summer or when doing less active work.

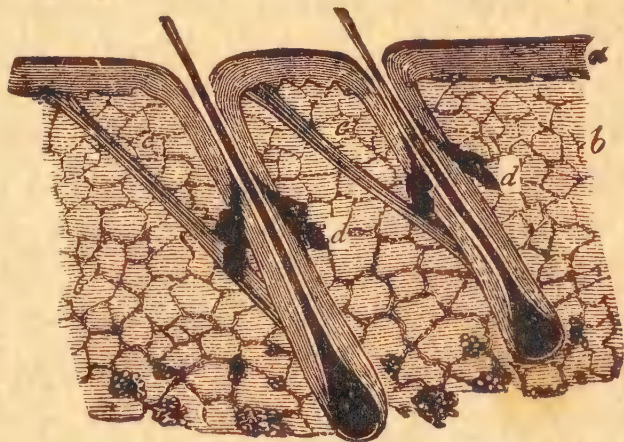


Fig. 69.—Section of the skin, showing hair follicles, sebaceous glands, and the muscles of the hairs.

(From Quain's 'Anatomy.'
By permission.)

a, epidermis; *b*, dermis; *c*, muscles of the hair-follicles; *d*, sebaceous glands.

Alongside this continuous production of heat there is going on loss of heat from the body, thus keeping the average surface temperature uniformly at $98^{\circ}\cdot4$ F. The loss of heat is due to the body being warmer than the surrounding air, the heat being lost by radiation, conduction and through evaporation of sweat. In summer however, when the surrounding air is often warmer than the body, the loss of heat takes place chiefly by evaporation of the large amount of sweat.

The temperature of the body is kept constant by the regulation of heat production and heat loss. Although the production and loss of heat is to some extent voluntary, i.e., under the control of the individual, as by exercise, use of warm clothes, baths, etc., the regulation of the temperature is involuntary and governed by the nervous system. Thus through the nerves going to the blood-vessels, the blood supply of the skin is regulated and the secretory action of the sweat glands controlled. That is how in cold surroundings, the skin becomes pale and anæmic preventing further loss of heat, while in a warm atmosphere it gets flushed and moist, thus increasing the loss of heat by radiation, conduction, and evaporation of sweat. We also use clothing to assist us in preventing undue loss of heat from the body. When not well provided with sufficient clothing in winter, we shiver, the muscles being thrown into involuntary contractions to produce more heat.



Fig. 70.--A Clinical Thermometer.

(From Paul's '*Domestic Economy*.' By permission.)

The temperature is usually taken by putting the bulb of the thermometer under the tongue or in the arm-pit, for a minute or so, and reading the degree to which the stem of mercury rises. Before using however, the mercury should be jerked to near the lower end of the scale and the thermometer well washed, preferably with a disinfectant.

The mechanism for regulating blood-supply is governed by a centre in the medulla oblongata of the brain. During heat stroke this centre is paralysed, the regulation of

temperature is interfered with, and the temperature rises very high— 106° F. or over.

The temperature of the body is taken by means of a clinical thermometer which is so graduated as to register temperatures from 95° to 110° F. The average temperature of the body in a state of health (normal) being $98^{\circ}\cdot4$ F.

The temperature is nearly the same in all parts of the body, the uniformity being brought about by the circulation of the blood. A slight rise may however be brought about by active muscular exercise. The feeling of heat or cold however, does not depend on the temperature of the body. It is well-known that even when the body temperature is high, as in fever, there may be feeling of cold or even shivering. This feeling entirely depends upon the state of circulation through the skin capillaries. When these vessels are full and the circulation active, there is a feeling of warmth, while when they are contracted and empty, we feel cold.

CHAPTER XVI

THE NERVOUS SYSTEM

THE Nervous System is the complex mechanism through which the whole body is co-ordinated and controlled. It regulates the various movements of the body, controls the secretions of various glands, is the part of the body in which the various sensations are translated into consciousness and is the seat of intellect, emotions, and will. It is in short the king sitting in his palace, protected by strong walls but in constant touch with the remotest portions of his kingdom and controlling and regulating the minutest details of every-day life.

The nervous system consists of two distinct parts, (i) the cerebro-spinal nervous system and (ii) the sympathetic nervous system.

The **cerebro-spinal nervous system** consists of the **brain** and the **spinal cord** and the various **peripheral nerves** arising from them.

The **sympathetic nervous system** consists of two chains situated one on either side in front of the vertebral column, and extending from the skull to the pelvis. On the course of these chains or cords are situated numerous small knots (**ganglia**) or collections of nervous matter from which fibres are given off to various internal organs and blood-vessels, as also branches connecting them with the spinal nerves. It regulates the movements of the internal organs such as the heart, lungs, stomach, etc., and is closely connected with the central nervous system by means of connecting nerves which proceed from the ganglia at various levels.

Nerve Cells.—The nervous matter forming the central and the sympathetic nervous systems consists of two kinds, described from their appearance as the **grey** and the **white matter**.

Under the microscope the grey matter is seen to consist chiefly of **nerve cells**, and the white matter of **nerve fibres**. A nerve cell is very characteristic, composed as it is

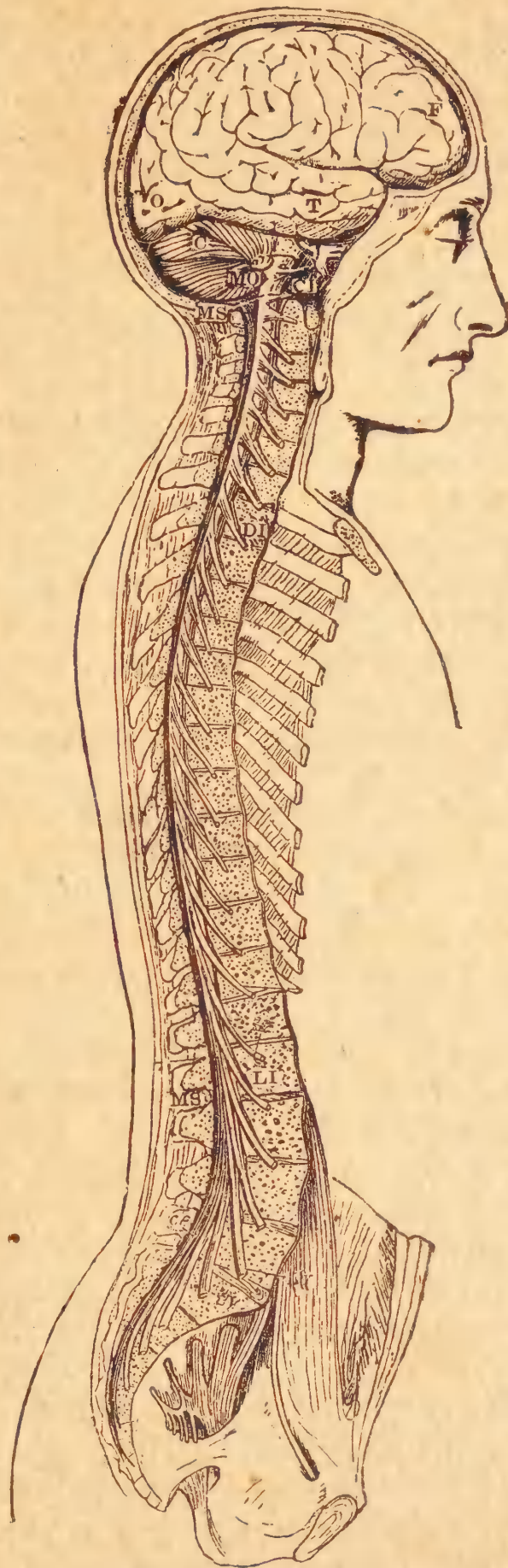


Fig. 71.—The Brain and the Spinal Cord contained in the Cranium and the neural canal, with the nerves coming off from the spinal cord.

(From Furneaux's 'Human Physiology.' By permission.)

F, T, O, frontal, temporal and occipital portions of the cerebrum ; c, cerebellum ; MO, medulla oblongata ; MS, spinal cord ; CI, the first spinal nerve from the cervical region ; DI, the first from the dorsal region ; LI, the first from the lumbar region.



Fig. 72.—The sympathetic nerve chain of the right side, showing branches given off to various internal organs, and connections with the spinal nerves.
(From Furneaux's 'Human Physiology.' By permission.)

of a central mass of protoplasm with its nucleus, and many processes given off from it. Most of these processes branch and interlace with those of neighbouring nerve-cells, but one of the filaments is distinguished from the rest by not branching except at its termination. This last is very long and covered by a sheath forms a nerve fibre.

Each nerve-cell with its processes is quite independent and is not connected with other cells except through the interlacing branches of its processes. A nerve-cell with all its processes is called a **neuron**. It is important to note

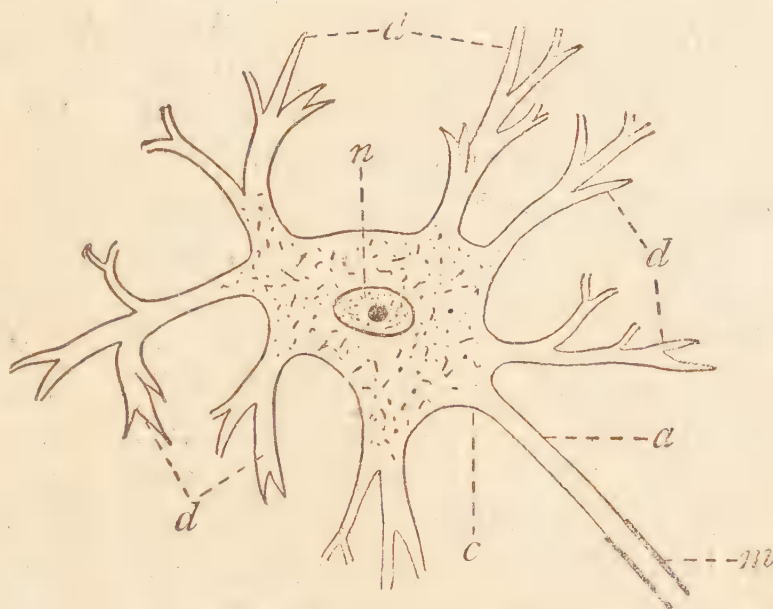


Fig. 73.—Diagram of a Nerve-cell from the grey matter of the spinal cord (highly magnified).

(From Thornton's 'Advanced Physiology.' By permission.)

c, body of the cell ; *n*, nucleus ; *d*, branching processes ; *a*, process which is very much drawn out and forms the axis of a nerve-fibre, being covered by a sheath (*m*).

that connection between one neuron and another is made through the contact of branching process and not through actual continuity of nerve matter.

The white matter consists of nerve-fibres which are continuations from the nerve-cells in the neighbouring grey matter. The whole of the nervous system is thus a collection of neurons.

Nerves.—A nerve is composed of numerous fine nerve fibres coming from neurons, bound together by fine connective tissue. Nerves have the appearance of fine white threads. On being teased out and examined under the

microscope, a nerve-fibre is seen to be composed of three different parts, viz., (1) the axis cylinder coming from a neuron in the brain or the spinal cord ; (2) a thick sheath of fatty substance covering the axis cylinder, called the medullary sheath ; and (3) a thin outer sheath, enclosing the whole nerve fibre.

Some nerve fibres particularly those of the sympathetic nervous system, have no medullary sheath, and are known as **non-medullated** nerve fibres.

Afferent and Efferent Nerves.—Nerves are classified into two varieties according to the direction in which they conduct nerve-impulses. A nerve impulse is a wave of disturbance which travels along a nerve from the site of stimulation. Nerves which carry impulses towards a nerve centre are called **afferent** (Lat. *af*, to ; and *fero*, I carry) **nerves**, and because they usually give rise to some sensation such as feeling of touch, sight, smell, etc., are often known as **sensory nerves**.

Nerves which bring impulses from a nerve centre to muscles, glands, etc., are called **efferent** (Lat. *e*., out ; and *fero*, I carry) **nerves**. If a nerve goes to a muscle and by carrying an impulse leads to its contraction, it is called a **motor nerve**. If it leads to secretion in a gland, it is **secretory**, and if it causes changes in the calibre of a blood-vessel, it is known as a **vaso-motor nerve**.

Thus all afferent nerves are not sensory, and all efferent nerves are not motor.

Some nerves are purely sensory, while others are purely motor. But the majority of nerves are mixed nerves, that is they contain both sensory and motor fibres and consequently can carry impulses in both directions.

The rate at which an impulse travels in a nerve is about 100 feet per second, which is very much less than the speed of light or even of an electric current.

The Brain.—The brain is the portion of the central nervous system, contained in the cranial portion of the skull. It is enclosed by three membranes, viz., the **dura mater**, the **arachnoid** and the **pia mater**.

The dura mater is the outermost, tough fibrous membrane, next to the skull. Inside it is a delicate membrane called the arachnoid, while within that closely investing the brain and dipping into its various furrows, is the pia mater.

This last is very vascular and supplies the surface of the brain with blood-vessels.

The brain consists of the following parts :—

1. The **cerebrum** or the great brain, is the large hemispherical mass, forming the greater portion of the brain.
2. Lying underneath the back portion of the cerebrum, is the **cerebellum** or the lesser brain.
3. Between the right and the left halves of the



Fig. 74.—Side view of the Human Brain

(From Quain's 'Anatomy.' By permission.)

The parts somewhat separated from one another.

A, cerebrum ; B, cerebellum ; C, pons Varolii ; D, medulla oblongata.

cerebellum is a bridge of brain substance, called the **pons Varolii**.

4. Beneath the pons and connecting it with the spinal cord is the elongated, **medulla oblongata**.

The Cerebrum.—The cerebrum is divided by a large longitudinal fissure into two equal halves called the **cerebral hemispheres**, but the two hemispheres are connected with one another by a band of nervous tissue, extending below the fissure.

Looked at from the outside the cerebrum is seen to be studded by numerous folds and furrows, called the convolutions and fissures of the brain. The larger of these fissures divide the cerebrum into several distinct lobes. The nervous matter of the brain consists of the grey and the white matter. In the cerebrum the grey lies outside and envelopes the white matter. It is therefore called the cortex. It consists of collections of neurons, forming centres which are concerned with particular functions of the brain. The white matter consists simply

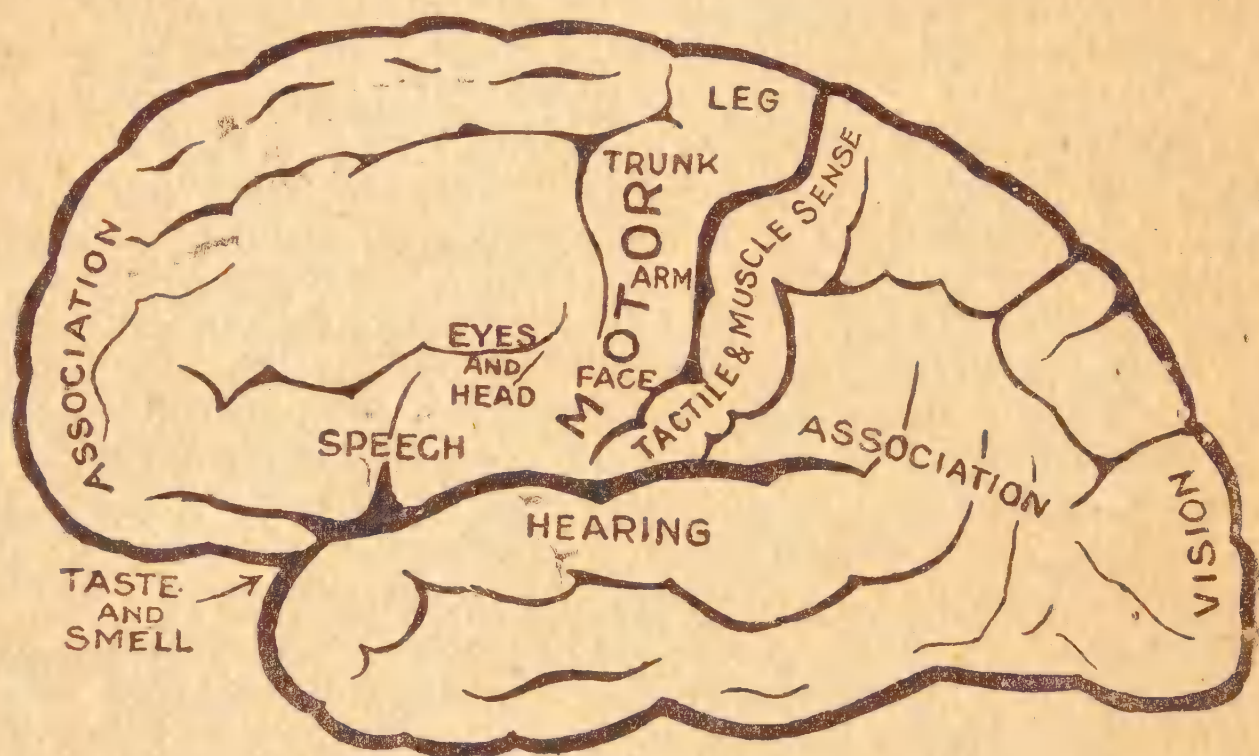


Fig. 75.—Diagram showing the localization of function in the cortex of left cerebral hemisphere.

(From Bainbridge and Menzie's 'Essentials of Physiology.'
By permission.)

of fibres of the neurons, coming from or going to the cortex. In the interior of each hemisphere is a distinct cavity known as the lateral ventricle.

Functions of the Cerebrum.—The functions of the cerebrum are numerous and complex. Sensations, thought, memory, will, action and emotions are all associated with it. The cerebrum is the seat of the **intellect**, that is enables us to think, learn, understand, judge and remember. It enables us to observe things around us, through one or other of our five senses (**sensation**). It gives us the power of **will** and

voluntary **action**. Further, this is the part of the brain which produces in us love, hatred, fear, joy, sorrow, etc., that is **emotions**. Different portions of the cerebrum are specialized to perform different functions. Some of them are receiving centres for impulses (sensory centres) while others originate impulses (motor centres). Most of the centres are located in the grey matter of the cortex. The functions of the cerebrum have been determined and the position of most of the centres found out as a result of experiments with animals or observations on persons with diseases of the brain. The following illustrations will give some indication of the nature of such experiments and observations :—

(1) If the cerebrum of a frog's brain is destroyed it sits up in the ordinary manner, breathes, swallows food placed in the mouth—making no attempt to feed itself, turns over and sits up if placed on its back, and swims if placed in water. If left alone it remains in the sitting posture till it dies. It is thus seen that it does nothing of its own accord, but only in response to stimuli received from outside by the spinal cord and the medulla. Such actions are described as **reflex actions**.

(2) If a person receives a blow on the top of his head, causing injury to the brain, he falls down and remains quite unconscious, without any power of moving. Under careful nursing the brain may repair the injury and the person recover his senses, and his powers of intellect, will and emotions, or if the injury is too severe, the person may pass off in that unconscious state.

(3) Some children are born with a cerebrum below the usual size, and are consequently found to be idiots. On the other hand, in the case of men with great intellectual powers, the cerebrum is always very large. Just as an athlete's arms and legs are more muscular, the cerebrum of an educated and thoughtful person is greater and more refined than that of the ignorant and careless people. The more diligently you work at your lessons, the more you are developing your cerebrum, and these mental faculties will be of use to you throughout life. Among the various subjects of study, mathematics is the best form of mental athletics.

(4) Intoxicating liquors affect this part of man's brain

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ARTIST

and a drunkard loses his intelligence and will power, and when greatly under their influence, becomes unconscious and falls down as dead drunk. If such a person does not give up this bad habit, he may become a victim of insanity.

The Cerebellum.—Lying underneath the back part of the cerebrum is the **cerebellum** or the lesser brain. It is a bilateral, furrowed structure, consisting of grey matter enclosing a core of white matter. The furrows are very much deeper than in the cerebrum and the pia mater dips into them to some distance.

The functions of the cerebellum are chiefly concerned with the co-ordination of muscular movements and the maintenance of the equilibrium of the body. Through this organ are received afferent impulses from the muscles and joints and from the semi-circular canals, and efferent impulses are sent which co-ordinate muscular movements in complicated acts, like walking, running, etc. If the cerebellum is injured the animal becomes giddy and loses his balance. He may still be able to contract a muscle but cannot run, walk, or perform other complicated movements requiring working together of many muscles.

Pons Varolii.—Pons Varolii (Lat. *pons*, a bridge,—bridge of Varolius) is a bridge like band of nervous substance passing above the medulla oblongata and connecting the two halves of the cerebellum. Fibres from the cerebrum also pass through it and as they pass they cross one another, fibres from the right cerebral hemisphere going through the left side of the pons to the muscles of the left side of the body, and from the left hemisphere to the right side. Thus an injury to the right cerebral hemisphere causes paralysis or loss of voluntary movement and loss of sensation on the left side of the body and *vice versa*. Just in front of it is a small globular body called the **pituitary body** which has important functions in regard to the development and the growth of the body.

Medulla Oblongata.—Medulla oblongata is a cylindrical mass of nervous tissue, lying between the two cerebellar hemispheres and connecting the brain with the spinal cord. Unlike the other parts of the brain, the grey matter in the medulla lies inside while the white matter is outside.

Medulla is a very important structure, as all the fibres passing from the spinal cord to the brain pass through it,

and in it are situated the important centres for respiration, circulation, etc. Medulla is thus the vital portion of the brain and any injury to it causes instant death.

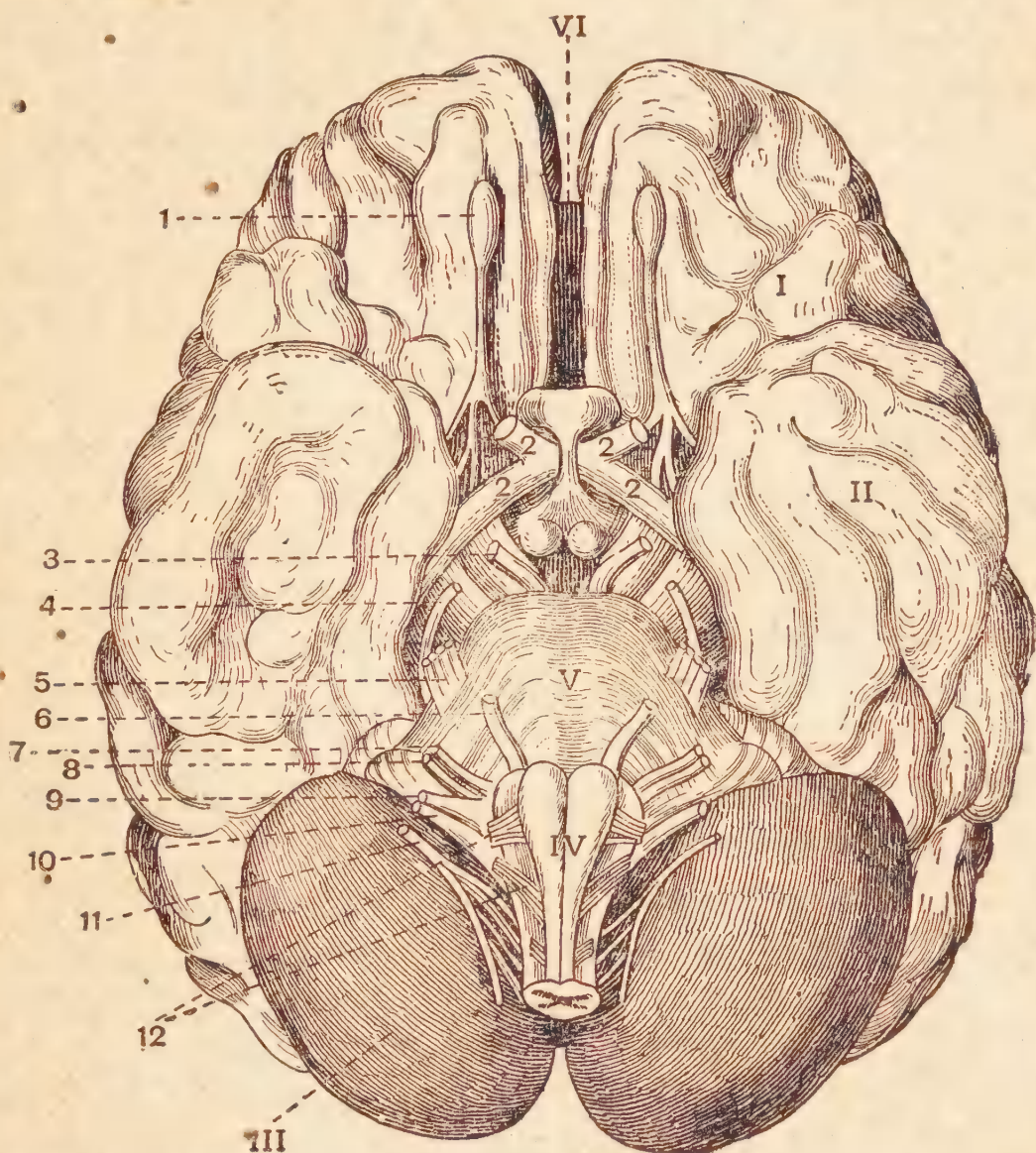


Fig. 76.—The under surface of the brain showing the origin of twelve pairs of nerves.

(From Thornton's 'Elementary Practical Physiology.'
By permission.)

I and II, lobes of the cerebrum ; III, cerebellum ; IV, medulla oblongata ; V, pons Varolii ; VI, the bridge connecting the two cerebral hemispheres. 1-12 the twelve pairs of cranial nerves arising from different parts of the brain.

Six pairs of cranial nerves arise from parts of the brain in front of the medulla, and the remaining six from the sides of the medulla.

Cranial Nerves.—Twelve pairs of cranial nerves arise from

the under surface of the brain, and they are numbered from before backwards. These pass out of the skull through small holes and are distributed for the most part to the sense organs, muscles or skin of the head, except the 9th, 10th, 11th and 12th, which send branches to other organs and parts of the body as well.

Most of the cranial nerves are purely sensory, a few are purely motor, while some, like all the nerves arising from the spinal cord, are mixed nerves.

The first or the **olfactory** nerve is a sensory nerve which terminates in the mucous membrane of the nose, and conveys the sensation of smell.

The second or the **optic** nerve, goes to the eyeball and is the nerve of sight. These nerves are seen to cross each other on the under surface of the brain, just in front of the pituitary body.

The third **oculo-motor**, fourth **trochlear** and the sixth **abducent** are purely motor nerves, and go to the various muscles which move the eyeball in different directions. There are six of these muscles, four recti and two oblique. Of these the superior oblique is supplied by the fourth nerve, the external rectus by the sixth and the remaining four muscles by the third nerve, which is thus the chief motor nerve of the eyeball (hence called oculo-motor).

The fifth is a mixed nerve, and is known as the **trigeminal**, because it divides into three branches. One of these is a sensory nerve, which spreads itself in the region surrounding the eyeball, nose, mouth, teeth and cheek and ends in the front surface of the tongue. This is the nerve which carries the sensation of pain in neuralgia of face and teeth, and also the sensation of taste. The two other branches of the trigeminal are motor and proceed to the muscles which move the jaws during mastication.

The seventh or the **facial** is a purely motor nerve for the face muscles and controls the facial expressions.

The eighth or the **auditory** is the nerve of hearing and goes to the internal ear.

The ninth is a mixed nerve. One branch is sensory and spreads over the back part of the tongue thus serving as a nerve of taste, and the other is motor for the muscles of the pharynx which are engaged in the act of swallowing. It is therefore known as the **glossopharyngeal**.

The tenth is a mixed nerve. It goes to the lungs, the heart, the liver and the stomach. Because of its wide distribution, it has been named **vagus** (*vagus*=wandering). On account of its giving branches, among others, to the lungs and the stomach, it is also called **pneumogastric**.

The eleventh is a motor nerve supplying certain muscles of the neck, and is called **spinal accessory** nerve.

The twelfth is a motor nerve supplying the muscles of the tongue and for that reason named the **hypoglossal**.

CHAPTER XVII

THE NERVOUS SYSTEM—(*Continued.*)

The Spinal Cord.—The spinal cord is a cord of nervous matter, occupying the neural canal running down the vertebral column. It extends from the foramen magnum of the skull, to the second lumbar vertebra, where it ends in a bunch of nerves. Like the brain it is covered by three membranes, the dura mater, the arachnoid and the pia mater. The spinal cord is divided into lateral halves by two fissures running in front and behind and known as the anterior and posterior fissures. In the centre is a

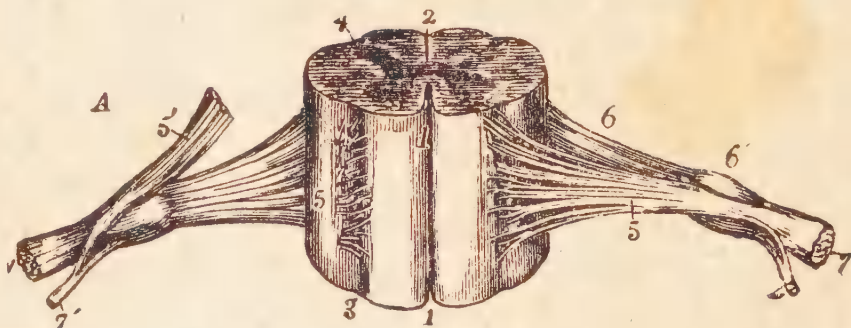


Fig. 77.—A portion of the spinal cord seen from the front and showing the origin of a pair of spinal nerves.

(From Thornton's '*Elementary Practical Physiology.*'
By permission.)

The darker H-shaped area in the middle is the grey-matter. 1, anterior fissure; 2, posterior fissure; 3, groove from which the anterior root arises; 4, groove for posterior root; 5, anterior root; 6, posterior root bearing 6', a ganglion; 7, the united nerve; 7', first branch from the nerve.

narrow cavity called the central canal of the spinal cord which is continuous with the ventricles of the brain. The various spinal nerves are given off on either side at regular intervals. There are thirty-one pairs of these nerves, and each nerve arises by two roots, an anterior and a posterior root, which unite each other while still within the neural canal. The nerves come out on both sides through the foramina between successive vertebræ. Like the brain the cord is composed of the grey matter and the

white matter, but the grey matter lies inside and the white matter outside completely surrounding the grey.

The grey matter is arranged in the middle of the cord resembling as seen in sections the capital H in shape. The limbs of H are curved and lie on either side of the central canal, pointing forwards and backwards. The parts in front of the connecting bridge are called the anterior horns and those behind the posterior horns. The grey matter of the cord is similar in structure to that of the brain, being composed of neurons and the fibres proceeding from them. The white matter of the cord is composed of medullated nerve fibres, intermingled with some fine connective tissue. These fibres are coming from or going to the various parts of the brain, bringing nervous impulses from the brain to the body, or carrying nervous impulses from the different parts of the body to the brain, the fibres from the right side of the body going to the left side of the brain and *vice versa*.

The anterior nerve root of the spinal nerve arises from the anterior horn and goes to muscles of the trunk or limbs and is therefore motor. If any motor root is destroyed the animal cannot move the corresponding muscles, but it feels the prick of a needle or any hot substance applied to the corresponding part.

The posterior nerve root of the spinal nerve enters the posterior horn. Its fibres arise in the skin covering different parts of the body and carry sensory impressions. It is therefore the sensory root. If it is cut the animal ceases to feel pain or the prick of a needle in the part supplied by the nerve, but is able to move the muscles supplied by the nerve. Thus every spinal nerve is a mixed motor and sensory nerve.

Functions of the Cord.—The spinal cord, as we have seen above, consists of fibres which run in the white matter and of nerve centres which are found in the grey matter.

The white matter is the conducting portion of the cord and transmits impulses to and from the brain. The impulses from the right side of the body go to the left side of the brain and *vice versa*. Any injury to the cord from disease or accident will prevent the conduction of these impulses, so that the person will not be able to move the limbs or other parts below the seat of injury, nor feel

any sensation of touch, pain, or cold from such parts. The parts are said to be paralysed. Life however will continue, so long as the injury to the cord is below the neck, from where the nerves supplying the diaphragm arise. If however portion of the cord in the neck is injured the diaphragm is paralysed and respiration cannot go on thus causing instant death.

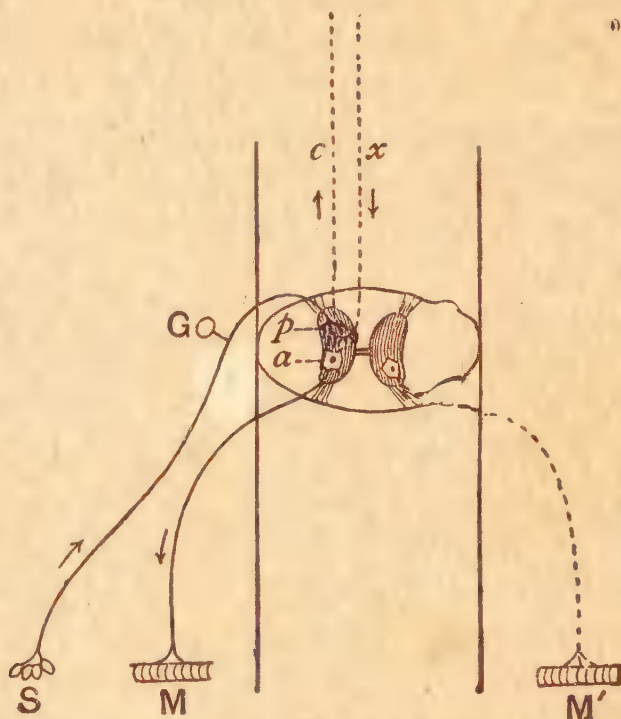


Fig. 78.—Diagram to illustrate the path of nervous impulses in a reflex action of the spinal cord.

(From Thornton's 'Elementary Practical Physiology.'
By permission.)

S, sensory surface from which a nervous impulse passes to the spinal cord by the posterior root of a spinal nerve; G, ganglion on the posterior root; the nerve-fibre breaks up at *p*, and transmits the impulse to a neuron *a*, in the anterior horn of grey matter; from *a* a motor impulse passes outward along a motor nerve to the muscle M. Sometimes an impulse passes to the other side of the cord, and thence to a muscle M' on the other side of the body. In actions other than reflex, the impulse to the brain is indicated by the dotted line *c* and the passage of an impulse from that organ by the dotted line *x*.

The neurons in the grey matter of the cord control the contraction of the various muscles supplied by the anterior root of the corresponding spinal nerve. Unlike the neurons in the grey matter of the cortex of the brain, they have no power to initiate movements. If the cord is injured, the muscles supplied from it below the seat of

injury cannot be moved at will as its connection with the brain has been cut off. But the animal moves its limbs if it is pinched or irritated, without the brain being concerned in these movements. In this case the nervous impulses conveyed to the cord by the sensory nerve fibres are reflected back by the spinal cord through the motor nerve fibres from the anterior horn, to the muscles of the limb. Such an action is called **reflex action**. Reflex action is movement that results from the stimulation of a sensory nerve, without our being conscious of it. The brain takes no part in these reflex movements. The centres in the spinal cord are called lower centres, because they are under the control of higher centres in the brain and have no power of initiating movements at will. They merely work like a machine.

Three structures are necessary for a reflex action, viz., (1) a sensory nerve arising from a sensory surface, (2) a centre in the cord or lower parts of the brain and (3) an efferent nerve going to a muscle or gland.

All the various actions that are performed as the result of external stimuli without our being conscious of them are reflex actions. Thus the act of winking if an object is suddenly brought near the eyes, is a reflex act. In this case the afferent nerve is the optic nerve, carrying the sensation to some centre in the brain, and the efferent nerve is the nerve supplying the muscles of the eyelids. Again if the sole of the foot is tickled even while we are asleep, the legs are drawn up. In this case the afferent nerve is the sensory nerve from the skin of the foot. The nerve centre is situated in the lower part of the cord and the efferent nerve is the motor nerve going to the muscles of the leg.

Other examples of reflex action are sneezing when the mucous membrane of the nose is touched, or flow of saliva when any acid substance is put on the tongue. In short most of the actions in our daily life such as walking, cycling, etc., become reflex acts after some time. In the beginning when walking or cycling are being learnt they are conscious acts done with the help of will and effort. But later on, they become purely reflex acts.

The Sympathetic Nervous System.—The sympathetic nervous system consists of a chain bearing a large number of ganglia or collections of neurons, lying on either side in

front of the vertebral column (Fig. 72). From the ganglia communicating branches are given off to the spinal nerves and other fibres run off to various internal organs and blood-vessels. These fibres form at various places in the body, exceedingly fine networks and supply the heart, lungs, stomach, intestines, urinary bladder and other abdominal organs and control their involuntary movements. As already stated the sympathetic system is connected with the centres of respiration, circulation, etc., situated in the medulla oblongata, through its connection with the vagus nerve.

The sympathetic system exercises an influence over the greater part of the internal machinery of the body, and to some extent controls the functions of digestion, circulation and respiration. Under certain circumstances such as fright, joy, grief, etc., the activity of these organs is influenced through the sympathetic system. A person under the influence of grief feels no appetite and as the result of fear the face becomes quite pale. On the contrary a happy news brings colour to the face and the person is said to blush. The emotions first spring up in the mind but their influence is extended to the sympathetic system, the fibres of which surrounding the walls of the blood-vessels in any part (say the face) exercise a more or less powerful control over them and a less quantity of blood is allowed to pass causing pallor or a greater quantity of blood passes causing the familiar blush.

CHAPTER XVIII

THE SPECIAL SENSES. TOUCH, TASTE, AND SMELL

Sensations.—It is through the nervous system that we derive a knowledge of the external world. This knowledge comes to us through sensations. Sensation is a feeling in consciousness produced by the stimulation of a sensory nerve. If it is due to the stimulation of a specially constructed sense organ, such as the eye or the ear, it is called a special sensation and it is distinctly local in character. Five special sensations are well known, viz., sensations of **touch, taste, smell, hearing** and **sight**. In addition to these there are special sensations of **pain** and **temperature**. But besides these special sensations there are others called common sensations, produced by the stimulation of widely distributed nerves by the state of the internal organs or blood. The commonest among these are hunger, fatigue, faintness and muscular sense. While there may be produced marked effect in some particular organ, such as the feeling of hunger in the pit of the stomach, the effect is general and distributed all over the body.

The **muscular sense** is regarded by some as a special sensation, because it is localized to muscles, but it is probably one of the common sensations as there are no special end organs or receptors which receive the stimulation from the outer world. It is through the muscular sense that we become acquainted with the condition of contraction of the muscles, the position of limbs, and are able to perform delicate movements or estimate the weight of a body.

The Special Sensations.—As explained above, sensation is the result of the stimulation of a sensory nerve, which transmits a message to the brain where the sensation is actually felt. The special structure which receives the stimulus and changes it into a **nervous impulse** is known as a **sense-organ**. Each of the special senses, touch, taste, smell, sight, and hearing, have sense-organs situated in particular parts of the body. These are only stimulated by a

particular form of energy, for which alone they are specially adapted. Thus the end organs of hearing is excited by sound waves, while that of sight by rays of light.

The irritation of a sensory nerve, through whatever cause, always produces the particular sensation to which it is related. Thus the excitation of the nerve of sight, as by pressure on the eyeball will produce flashes of light, and the irritation of the nerve of hearing from whatever cause will produce the sensation of sound.

Touch.—The sense of touch is widely distributed all over the surface of the skin. It is caused by the stimulation of end-organs of touch or nerve-endings of sensory nerves in the skin and mucous membranes of the mouth and nose, etc. These are called **touch corpuscles** (Fig. 67) and are composed of a mass of cells in which a branch of sensory nerve ends. The sense of touch is most delicate in the tip of the tongue, the tips of fingers, the tip of the nose, and the lower lip. In these places the touch corpuscles are most abundant and are covered only by a thin layer of epidermis.

The sensitiveness of the skin is determined by the ability to distinguish between the points of a pair of compasses placed near together on the surface of the skin. The nearer are the two points which are distinctly felt as separate, the more sensitive to touch is that part. Thus while on the tip of the tongue the two points can be felt as distinct when the distance between them is only $\frac{1}{24}$ of an inch, on the back of the body, it has to be about three inches before two separate points are felt as such. Hence the tip of the tongue is seventy-two times more sensitive than the back of the body.

Temperature and Pain.—Like the sense of touch, the senses of temperature and pain are caused by the stimulation of special corpuscles. These are distributed under the epidermis and are different from the touch corpuscles. The parts most sensitive to temperature are the tip of the tongue, the eyelids, the cheeks, the lips and the hands. It is interesting to note that the skin is not a good judge of the absolute temperature of bodies. Thus if one hand is placed for some time in hot water and the other in cold and then both are placed in tepid water, the same water will feel cold to one and warm to the other. This is due to the fact that the sense of temperature is modified by the

state of blood-vessels of the skin, blood-vessels that are full make us feel warm and blood-vessels that are empty make us feel cold.

Taste.—The tongue is a muscular organ which lies in the



Fig. 79.—Upper surface of the tongue.

(From Thornton's 'Elementary Practical Physiology.'
By permission.)

d, back of the tongue connected with *c*, the hyoid bone; *e*, branch of ninth cranial nerve (taste); *f*, branch of twelfth cranial nerve to muscles of the tongue (movement); *g*, branch of fifth cranial nerve (taste); *h*, circumvallate papillæ; *i*, fungiform papillæ; *k*, filiform papillæ.

mouth cavity and is attached at the base by a fold of mucous membrane. The tongue is covered by mucous membrane which is smooth on its under surface but is rough and irregular on the upper surface on account of the projections called papillæ. The papillæ are of three

kinds: (1) Ten or twelve **circumvallate papillæ** arranged in the form of a V at the back of the tongue. Each of these is a roundish projection surrounded by a trench and a wall. (2) **fungiform papillæ** are smaller and distributed over the surface, chiefly at the sides and the front. (3) **filiform papillæ** are the smallest and most numerous and occur over the whole surface of the tongue. These papillæ contain small collections of cells called **taste-buds** in which the nerves of taste terminate.

The tongue is supplied by three nerves, the fifth, ninth and twelfth cranial nerves. The fifth and the ninth nerves are sensory, the former supplying the front and middle portions of the tongue while the latter, the back portion. Both these nerves are nerves of taste. The twelfth cranial nerve is a motor nerve and controls the various movements of the tongue in rolling the food about and in speaking.

The sensation of taste is brought about by the stimulation of the taste-buds by substances in solution, the stimulation being transformed into nervous impulses and conveyed to the brain by the nerve fibres. It is essential that the substance to be tasted should either be in solution or capable of being dissolved in saliva. This can be illustrated by wiping the tongue dry and putting on it a little bit of salt, when no taste will be felt, till the salt begins to dissolve. There are only four kinds of taste, bitter, sweet, salt and acid and they are perceived through stimulation of different taste-buds. Thus while the tip of the tongue is most sensitive to sweets, the back part is most sensitive to bitter substances. All other tastes are only admixtures of these four fundamental tastes. In many of the tastes however the sense of smell is closely associated. The flavours of various substances are mainly due to their odour. That explains the common practice of holding one's nose while taking a nauseous medicine. This is also the reason why a bad cold in the nose prevents the enjoyment of the flavours of various articles we eat.

Smell.—Nose is the organ of smell. The cavity of the nose is lined by mucous membrane which is richly supplied by nerves and blood-vessels. The upper part of each nostril is supplied with branches of the first cranial or the special nerve of smell. The lower part of each nostril

serves for breathing. It has nothing to do with the sense of smell. In ordinary quiet breathing when the air passes through the lower part, no smell is sometimes felt and to perceive very delicate odours one has to 'sniff' the air which brings the odorous particles into more direct contact with the end organs of smell.

The terminations of the olfactory nerve are only excited by molecules of vapours reaching the cells of the olfactory

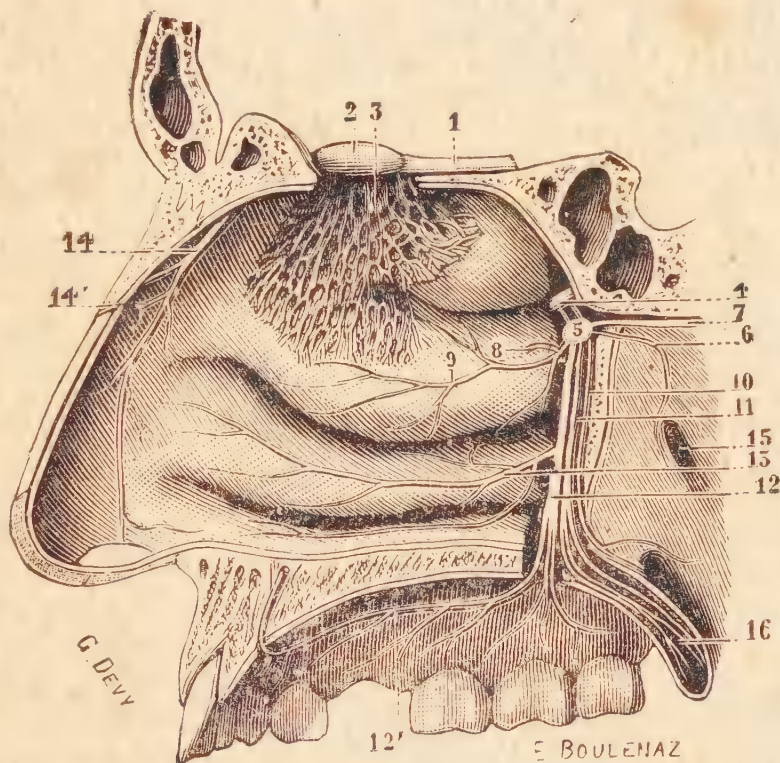


Fig. 80.—Outer wall of nasal cavity.

(From Thornton's 'Elementary Practical Physiology.'
By permission.)

The three turbinated bones are seen covered by mucous membrane. 1, olfactory nerve in cranium; 2, its dilated end; 3, branches of olfactory nerve in nasal cavity; 5, a nerve ganglion with branches of the fifth cranial nerve below proceeding to lower part of nose and palate. Other numbers refer to unimportant details.

epithelium and this stimulation generates a nervous impulse which is transmitted to the brain. All smells are therefore due to vapours and substances which do not give off any vapours have no smell.

The loss of smell during a bad cold is due to the fact that mucous membrane gets swollen and prevents the access of air from the lower to the upper part of the nose where the olfactory cells and terminations of the olfactory nerves are situated.

CHAPTER XIX

THE EYE AND VISION

Protection of the Eyeball.—The eye is the organ of sight and lies in the bony cavity of the skull called the orbit. It is like a ball and the second cranial or optic nerve connects it with the brain. In front the eyeball is protected by the **eyelids** which are moveable folds of skin and muscle. The inner surface of the eyelids is covered by a thin mucus membrane called the **conjunctiva** which is also reflected on to the front of the eyeball. The edges of the eyelids are studded with tiny hairs called **eyelashes**. By the contraction of the muscles of the eyelids they can be closed, the upper eyelid has in addition a muscle which can raise it.

The conjunctiva is kept moist by a saltish fluid produced continuously by the **tear gland** situated in the upper and outer part of the orbit. This fluid spreads over the whole of the conjunctiva and after washing the anterior surface of the eye collects in the inner angle of each eye and passes through two small holes, into the nasal ducts and conveyed to the nose. When from any cause such as irritation by vapours or as the result of strong emotion, there is abundance of this secretion and the nasal ducts cannot carry away the fluid, it overflows on to the cheeks as tears.

Movements of the Eyeball.—The eyeball is moved in various directions by means of muscles which are attached to its outer surface. They are six in number, four **straight** and two **oblique**. The four straight or recti muscles come from the back of the orbit and are inserted above, below and on each side of the eyeball, turning the front of the eyeball upwards, downwards, outwards and inwards respectively. The oblique muscles bend in their course. The superior oblique reaching near the front becomes tendinous and passing over a pulley turns backwards to be inserted on the outer and back portion of the eyeball and thus turns it obliquely outwards and downwards. The inferior oblique

is inserted on the outer and under surface of the eyeball and turns it outwards and upwards.

Separately or in combination these muscles turn the eyeball in various directions. Both the eyes are ordinarily moved together in the same direction, so that the axes of the eyeballs remain parallel; when the eye looks at a near object both the eyes are turned inwards. If however there is some defect in the muscles and they are not properly co-ordinated, squint result, and objects are seen double.

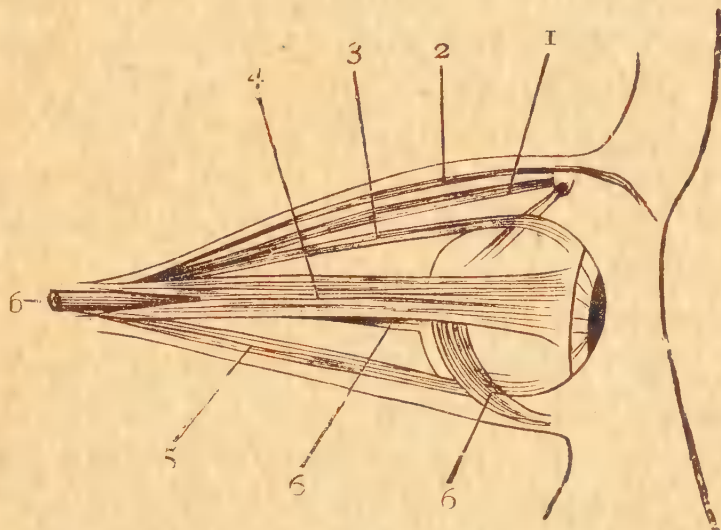


Fig. 81.—Diagrammatic representation of the muscles of the right orbit.

(From Thornton's 'Elementary Practical Physiology.'
By permission.)

1, superior oblique muscle passing over a pulley to its insertion; 2, muscle which raises the upper eyelid; 3, superior rectus muscle; 4, external rectus muscle (the internal rectus not seen); 5, inferior rectus muscle; 6, 6, optic nerve; 6, inferior oblique muscle.

The Eyeball.—The eyeball is not quite globular being less from before backwards and from above downwards than from side to side. From side to side it is about one inch in diameter. The front portion of the eyeball bulges slightly, being portion of a smaller sphere. When the eyeball is dissected its wall is seen to be composed of three coats or layers which enclose two spaces or chambers filled with transparent substances. The three coats from without inwards are—

- (a) The sclerotic and cornea.
- (b) The choroid and iris.
- (c) The retina.

The **sclerotic** or the white of the eye is the thick fibrous coat which covers the posterior five-sixths of the eyeball and is continued in front into the transparent circular portion that bulges forward and is called the **cornea**. When you look at a person's eye from the front, portion of the sclerotic is seen as the opaque white region surrounding the central

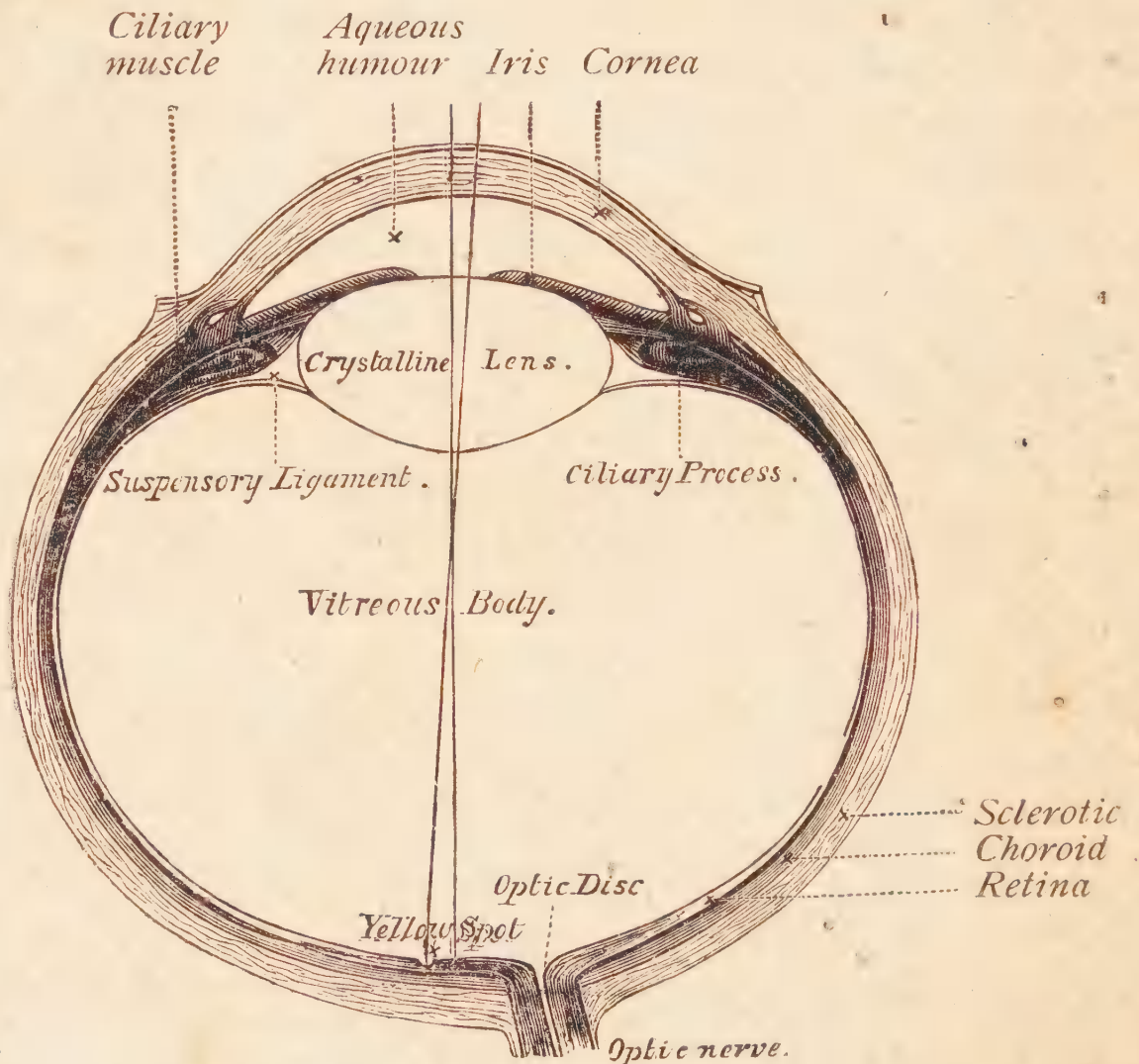


Fig. 82.—Horizontal section of the left eyeball.
(From Waller's 'Human Physiology.' By permission.)

circular cornea, which is transparent but appears to be dark, or brown, or blue according to the colour of the iris lying behind it and shining through it. The sclerotic is pierced behind by the thick cord like **optic nerve**, while to its outer surface are attached the various muscles which move the eyeball in various directions.

The **choroid** is the dark brown membrane lying internal to the sclerotic and loosely attached to it. It consists of

connective tissue containing numerous blood-vessels and pigment cells. Its function is to darken the chamber of the eye and prevent reflection of light. Like the sclerotic it is pierced behind by the optic nerve. In front it becomes continuous with the **iris**, a coloured circular curtain which lies some distance behind the cornea. But just before passing into the iris the inner surface of the choroid is thrown into a number of folds or plaits known as the **ciliary processes**,

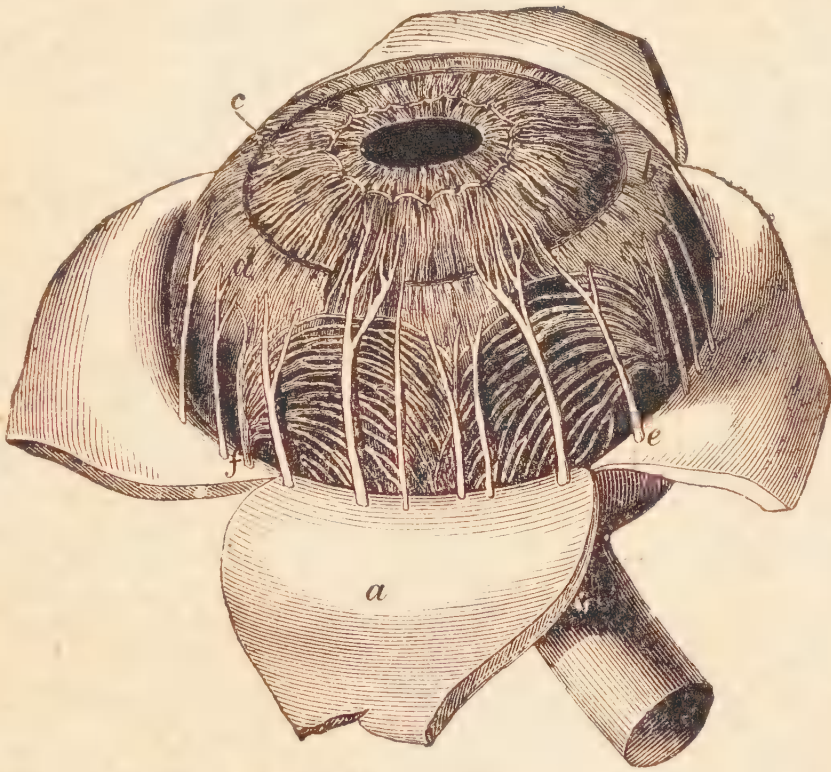


Fig. 83.—The Choroid and Iris exposed.
(From Quain's 'Anatomy.' By permission.)

The cornea has been removed and flaps of the sclerotic turned back. *a*, portions of the sclerotic turned back; *b*, ciliary muscle; *c*, iris; *e*, one of the ciliary nerves; *f*, blood-vessel.

and on the outer surface is seen a circular band of muscle, called the **ciliary muscle**. The ciliary muscle arises from the inner surface of the junction of the sclerotic and cornea and passes backwards to be inserted into the outer surface of the junction of the choroid and iris. Thus when it contracts it pulls forward the choroid, with the ciliary processes fitting into the capsule of the lens; the capsule thus relaxes its hold on the lens and allows it to become more convex.

The **iris** is the circular dark curtain which is seen through the transparent cornea. In its middle there is a

circular opening or window called the **pupil**. The iris contains muscular fibres some of which are arranged circularly and others radially around the pupil. The circular fibres by their contraction narrow the opening of the pupil while the radial dilate the pupil. The iris thus regulates the amount of light that enters the eye and fulfils the same purpose as the diaphragm of a camera or a microscope. Both sets of fibres are involuntary and their action is purely reflex. When the eye is closed or turned away from light, the pupil dilates and when the eye is opened and turned towards light, the pupil is seen to contract.

The iris gives the colour to the eye which differs in different persons and races. It consists of connective tissue containing pigment cells. The back surface of the iris is like the choroid quite dark.

The **retina** lies internal to the choroid to which it is loosely attached. It is an expanded outgrowth of the optic nerve and lines about two-thirds of the interior of the eyeball. The point where the optic nerve enters is called the optic disc or the **blind spot**, as light falling on it does not produce any sensation. Exactly in the centre of the retina, corresponding to the axis of the eye is an area called the **yellow spot**. At this spot vision is most acute.

When sections of the retina are examined under the microscope, it is found to consist of numerous layers. Of these the most important is the layer of rods and cones. These are the structures which are sensitive to light and the sensitiveness of any part of the retina depends upon the number of the rods and cones present at the spot. At the blind spot these are absent, whilst they are most numerous at the yellow spot, where the vision is most acute. The fibres of the optic nerve convey the visual impressions to the brain. We are not ordinarily aware of the blind spot in the eye, but a simple experiment can demonstrate its existence.

Close the left eye and with the right eye gaze steadily at the cross in the above figure, holding the book upright at about twelve inches from the face. The circle is also seen. Now move the book slowly towards you and at a certain distance the white circle disappears, as its image is now falling on the blind spot. The black back ground

appears to be continuous, showing that the gap is unconsciously filled up. On bringing the book closer, the circle is seen again.

The Chambers of the Eye.—The iris stands as a vertical curtain and divides the interior of the eyeball into two cavities or chambers, the smaller **anterior chamber** lying between the iris and cornea and the larger **posterior chamber** lying behind the iris and enclosed by the retina. The anterior chamber is filled with a clear, watery, transparent fluid called the **aqueous humour**. The posterior chamber is filled with a transparent jelly-like substance enclosed in a membrane and known as the **vitreous humour**, which supports the crystalline lens situated just behind the iris. The aqueous humour, the crystalline lens, and the vitreous



Fig. 84.—To demonstrate the blind spot.

(From Starling's 'Principles of Physiology.' By permission.)

humour serve as the refractive media of the eye, bending the rays of light entering the eye so as to bring them to a focus on the retina and thus produce a distinct impression.

The **crystalline lens** is perfectly transparent, convex in front and behind, and lies immediately behind the pupil in the iris. Its posterior surface fits into a depression in the vitreous humour. It is enclosed in a transparent elastic capsule which on either side is attached to a prolongation known as the suspensory ligament of the lens. The suspensory ligament plays an important part in varying the curvature of the lens in order to enable it to bring to focus on the retina rays of light now from a near and now from a distant object. These variations are brought about by the

action of the ciliary muscle on the suspensory ligament of the lens as mentioned before.

Vision.—Before any object can be seen it is necessary that the rays proceeding from it should be focussed on the retina. In nature, rays proceeding from a near object are invariably divergent, while those proceeding from objects at distances above twenty feet are more or less parallel. Before these divergent or parallel rays can be focussed on the retina, it is obvious that they should undergo some bending or refraction. This change of divergent or parallel rays into convergent rays is brought about by a double convex lens. A double convex lens has both its surfaces convex and so is thickest in the middle and thinnest at the margins.

To demonstrate the formation of images by a convex lens a few simple experiments may be performed:—

(1) Hold a convex lens facing the sun, placing behind it a sheet of paper to act as a screen. Now move the lens to and from the screen, till a bright spot is formed on it. This is produced by the rays of light converging to a point in passing through the convex lens.

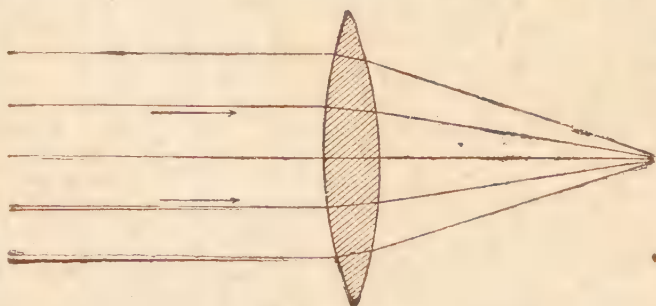


Fig. 85

(From Furneaux's 'Human Physiology.' By permission.)

(2) Now light a candle inside a room and put the lens facing the candle flame at a distance of a few feet, holding a screen behind. At a certain distance from the lens an inverted image of the candle is formed on the screen (Fig. 86). Move the lens nearer to or farther from the screen and note the place where the image is clear and brightest. The screen is now said to be placed at the focus of the lens and the distance between the lens and the screen known as the focal distance of the lens.

The formation of an inverted image shows that the rays

from the luminous object have crossed each other in passing through the lens. If the candle is brought nearer the lens, the distinct image is formed further behind (Fig. 87) and *vice versa*.

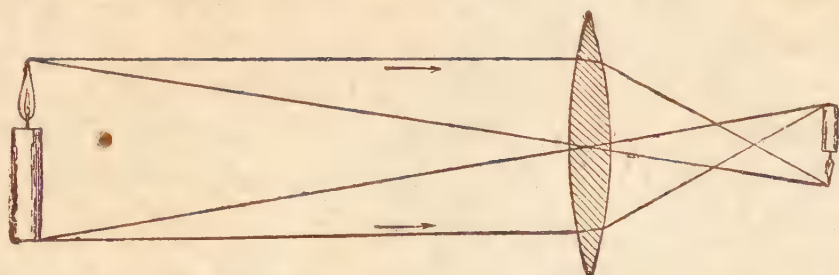


Fig. 86

(From Furneaux's 'Human Physiology.' By permission.)

(3) Next take a lens with more convex surfaces and repeat the above experiment. We find that to get a distinct image on the screen the distance between the lens and the screen is much less because there is now greater bending of the rays. By repeating the experiment with several lenses we find that the more convex the lens, the shorter the distance at which distinct image is produced.

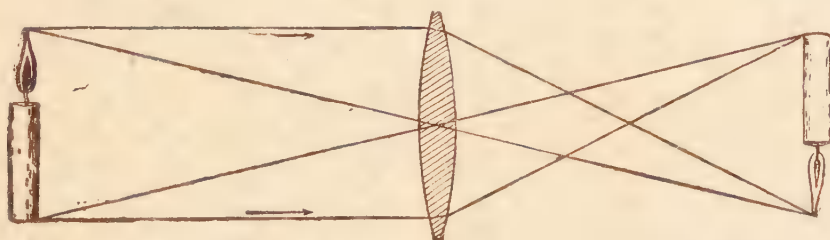


Fig. 87

(From Furneaux's 'Human Physiology.' By permission.)

Thus we have learnt that (1) a convex lens forms an inverted image of an object, (2) the nearer the object is to lens, the greater the distance between the lens and the screen and (3) the more convex the lens, the shorter the distance at which the distinct image is formed.

In the eye, the convergence of the rays coming from various objects you look at is effected by means of various refractive media, viz., cornea, the aqueous humour, the lens and the vitreous humour. In a normal eye, they enable the rays of light coming from various objects to form a clear image on the retina. These images produce a visual sensation which is conveyed through the optic nerve.

to the brain where perception or conscious vision takes place. Sight would be interfered with if there is some defect in the refractive media, the retina, optic nerve, or the part of the brain which receives the visual sensations.

Power of seeing Objects at Different Distances.—The objects looked at are at varying distances from the eye, while the point at which they have to be focussed is always the same distance behind the lens in any eye. It is obvious therefore, that the lens must have the power of varying its convexity if clear images are to be formed on the retina. The power of the lens by which it is able to form distinct images on the retina of both distant and near objects is called **accommodation**. The normal eye is so constructed that rays coming from a distance (which are parallel rays for all practical purposes) are focussed on the retina without any accommodation. But for distances less than twenty feet effort of accommodation is needed. As the distance between the retina and the lens of the eye is fixed and unalterable, the lens increases in convexity when looking at near objects. This is brought about by the action of the ciliary muscle pulling forward the choroid and the ciliary processes, thus loosening their hold on the suspensory ligament of the lens, and enabling the lens to bulge forwards. The nearer the object looked at, the greater will be the contraction of the ciliary muscle and the consequent greater convexity of the lens. Too much of near work such as reading and writing, by throwing too much strain on the ciliary muscle, tends to weaken the muscle and ultimately cause myopia or short-sight.

Binocular Vision.—In looking at an object with both eyes images are formed on both the retinas and for an object to appear single, it is necessary that the images should be focussed on the corresponding positions of the two retinas. The seat of clearest vision is the yellow spot and therefore in looking at a near object, the eyes must converge if the object is to be seen single, so that the image may be formed on the yellow spot in each eye.

This is effected by means of the muscles of both eyes always working in co-operation. Convergence and accommodation always take place together in the two eyes. By looking at objects with two eyes we get a better idea of the form of the objects and their respective position in

space. This principle is imitated in looking at pictures through the stereoscope, when the objects represented in the picture, stand out in relief and vivid idea of the panorama is conveyed.

Some Visual Sensations.—The retina gets easily tired. Thus if we look at a bright light for some time and then turn and look at a white paper we see on it a dark spot. It is because the portion of the retina on which bright light had been falling has become tired and insensible. The retina is able to retain the impressions made upon it for about $\frac{1}{8}$ of a second after the object looked at has been removed. If a succession of moving pictures is shown on a screen at such a speed that the image of a new one is formed while the image of the last has not faded, objects will appear to show life-like movements on the screen. This is the principle of the cinematograph. Many other examples of daily occurrence can be easily recalled. Thus a lighted stick moving rapidly round appears as a lighted circle or an ascending rocket produces a trail of light.

White light is composed of seven colours, violet, indigo, blue, green, yellow, orange and red, the colours composing the rainbow. This can be demonstrated by passing a ray of light through a prism which splits it into its seven component colours and produces a **spectrum**. If you look steadily for a few minutes on a red spot on a white paper and then turn the eyes on to clear white paper, you see a bluish green spot. This is due to the fact that the portion of the retina on which the red rays fell has got tired so far as the red rays are concerned, but remains sensitive only to other components of white light. Therefore red and green are called **complementary colours** and mixed together give the sensation of whiteness. Yellow and blue are also complimentary colours. If the retina is fatigued by one of these colours it perceives the complimentary colour when looking at white light.

Some people are 'Colour blind' that is to say are incapable of recognizing differences between certain colours. The defect is due to some defect in the retina.

Defects of Vision.—If we take a book and hold it at a distance of twelve inches from us we can easily read the letters. If the book is brought nearer and nearer, a point is reached at about four or five inches from the eyes, when the letters

become indistinct. This is due to the fact that accommodation has reached its limit. The point is called the **near point**.

In old age as the ciliary muscle becomes weaker and the lens inelastic, the power of accommodation gets less and consequently the near point recedes. People after the age of forty-five are therefore not able to read at near distance but can see distant objects with ease. They consequently need convex glasses for reading purposes.

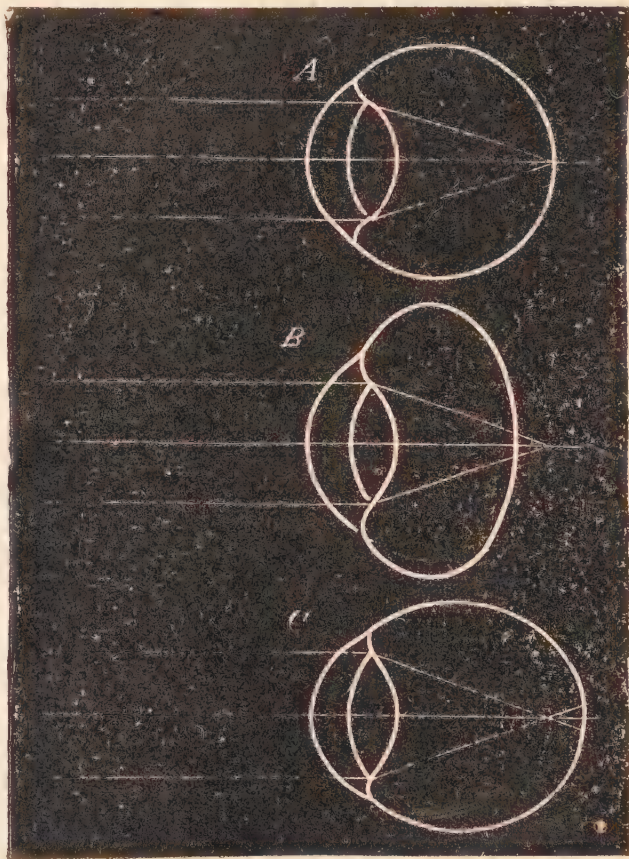


Fig. 88.—Diagram of course taken by Parallel rays on entering the eye.

(From Starling's '*Principles of Physiology*.' By permission.)

A, normal eye, parallel rays focussed on the retina.

B, hypermetropic or long-sighted eye, parallel rays focussed behind the retina.

C, myopic or short-sighted eye, parallel rays focussed in front of the retina.

A normal eye, as already stated, is so constructed that parallel rays, and rays coming from objects beyond twenty feet are parallel for all practical purposes, are focussed on the retina without any effort of accommodation.

If, as some times happens, the eyeball is comparatively too short so that rays coming from distant objects are focussed behind the retina and produce indistinct vision,

and bringing the object nearer the eye makes the image still more indistinct, the person cannot see objects distinctly at any distance unless accommodation is used. He is victim of headaches even when not putting any strain on the eyes. While reading he tries to keep the book as far away as possible. He is consequently said to be suffering from **long sight** or **hypermetropia**. He needs converging or convex glasses to be used constantly. It must however be remembered that glasses should be worn as prescribed after examination by a qualified doctor. This defect is usually congenital.

If however the eyeball is too long and the parallel rays coming from a distance are not focussed on the retina but in front of it, the image formed is indistinct. The person therefore has to bring the object nearer to his eyes or reach closer to it in order to see distinctly. He is therefore called **short-sighted** or **myopic**. Such a person needs suitable concave glasses to see things properly, as such lenses will scatter the rays and they will be focussed on the retina. This defect is usually acquired from reading fine print or doing other fine work at an early age.

There is one more defective condition of the eye which is fairly common. It is called **astigmatism**. In this the curvature of the cornea is not uniform in all its diameters, so that some portions of the image are focussed on the retina while other portions are focussed either behind or in front of it. Such a person while looking at a cross sees one or the other of the arms indistinctly. In some cases the eye may be myopic in one meridian and hypermetropic in the other. The person needs compound glasses that is lenses which are not regular in all the diameters. It is obvious that such glasses have to be worn constantly. This defect may be congenital or acquired.

CHAPTER XX

THE EAR AND HEARING

The Organ of Hearing.—The ear is the organ, by means of which sound waves are collected and converted into a nervous impulse to be transmitted to the brain. The

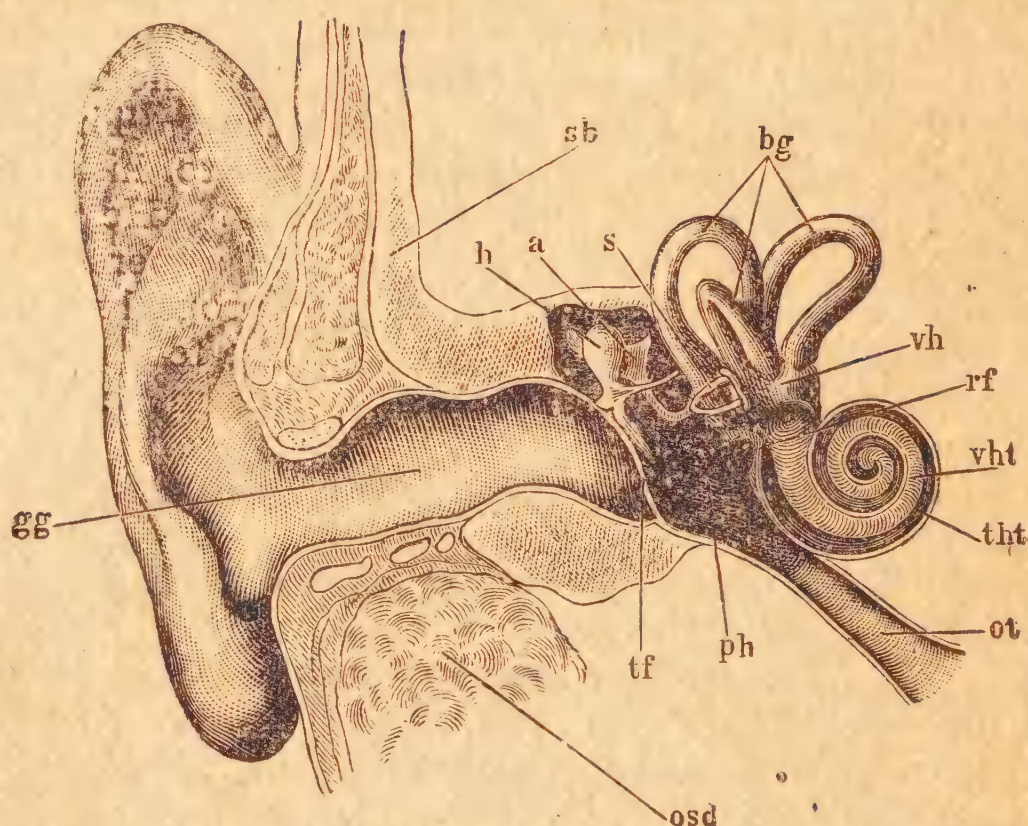


Fig. 89.—Outer ear, middle ear, and parts of the inner ear.
(From Thornton's 'Elementary Practical Physiology.'
By permission.)

gg, auditory canal ; tf, drum or tympanic membrane ; ph, cavity of middle ear ; h, hammer bone or malleus ; a, anvil bone or incus ; s, stirrup bone or stapes with the foot-plate against the oval window of the inner ear ; rf, fenestra rotunda or round window ; ot, eustachian tube ; bg, bony semi-circular canals ; vh, vestibule ; tht, cochlea ; vht, interior of cochlea ; osd, bone cut through.

sound waves are collected by the outer expanded portion popularly known as the ear, which is in reality only the **external ear**. This leads into a narrow passage called the **auditory canal** which is closed on the inner side by a thin

circular membrane called the drum of the ear or the **tympanic membrane**. The tympanic membrane separates the outer from the middle ear. The **middle ear** or tympanum is a small cavity in the temporal bone, containing a chain of three small bones which connect the tympanic membrane with the internal ear. The **internal ear** consist of a very complex apparatus situated in the inner projecting portion of the temporal bone, in the interior of which there are special sensory cells to which the fibres of the auditory nerve are distributed.

The External Ear.—The external ear consists of an irregular plate of cartilage covered by skin, leading into the auditory canal. The canal is about $1\frac{1}{4}$ inch long. It leads obliquely inwards and forwards to the drum, and is lined with a thin layer of skin which has hair and contains glands secreting the ear wax. The hair and the wax serve to catch the dust which might otherwise irritate the tympanic membrane.

The Middle Ear.—It is an irregular cavity situated in the temporal bone. It is lined by mucous membrane and filled with air. It is separated from the external ear by the circular tympanic membrane, and from the brain by the piece of bone enclosing it. Thus it is that any discharge from the ear is a serious thing, as it may lead to an abscess in the brain. On the inner and under side is a narrow channel called the **Eustachian tube**¹ which leads into the pharynx. In this way the cavity of the middle ear communicates with the air outside, and the pressure on the two sides of the drum is equalized. In case of a sudden loud noise air is allowed to escape into the pharynx, thus preventing rupture of the membrane. This tube is also the channel through which inflammation may travel from the throat to the middle ear, an occurrence fairly common in children. Behind, the cavity of the middle ear communicates with small spaces in the temporal bone. In cases of discharging ears there is always a danger of pus infecting these spaces causing an abscess which if not opened in time may lead to an abscess of the brain and death. In the inner wall of the middle ear there are two

¹ Named after an Italian anatomist, Eustachius, who lived in the sixteenth century.

small openings closed by membrane. One, oval in shape and the other, round.

Extending from the tympanic membrane to the inner wall of the middle ear is a chain of three small bones by means of which vibrations received by the drum are conveyed to the internal ear. They are named the *malleus* or hammer, the *incus* or anvil and *stapes* or the stirrup. The malleus is attached to the drum of the ear, while the

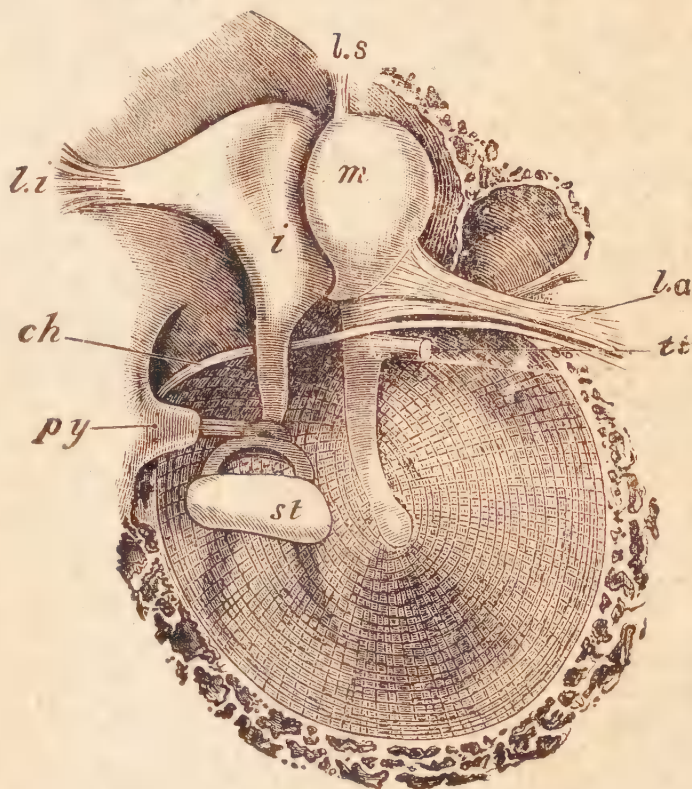


Fig. 90.—Inner aspect of the drum of the left ear, and the small bones of the middle ear.

(From Quain's 'Anatomy.' By permission.)

m, malleus; *i*, incus; *st*, stapes; *py*, pyramid through which tendon of muscle of stapes emerges; *tt*, tendon of a muscle attached to handle of malleus; *l.a.*, *l.s.*, and *l.i.*, ligaments holding the bones; *ch*, branch of the facial nerve.

foot-plate of the stapes fits into the oval window leading to the inner ear.

The Internal Ear.—The internal ear is the complicated irregular-shaped apparatus situated inside the pyramidal internal portion of the temporal bone, and on account of its complicated form is known as the **labyrinth**. Inside the **bony labyrinth** is contained a closed membranous sac of the same form known as the **membranous labyrinth**. The mem-

branous labyrinth contains a clear fluid called the **endolymph**, while between it and the bony labyrinth is another fluid known as the **perilymph**.

The labyrinth is the essential part of the organ of hearing and contains the termination of the eighth cranial or the **auditory nerve**. It consists of three parts, (1) the **vestibule**, (2) the **cochlea** and (3) the **semi-circular canals**.

The **vestibule** is the central chamber which communicates with the cochlea in front and the semi-circular canals behind. In its wall is the oval window into which the plate of the stapes is inserted.

The **cochlea** is a spiral structure situated below and in front of the vestibule, resembling the shell of a tiny snail. In the membranous cochlea are found the terminations of the auditory nerve. The fibres of the nerve are connected with the special end organ of hearing known as the **organ of Corti**¹ which is very complex in structure, and consists of a large number of rods and cells. Viewed from above the organ of Corti resembles the key-board of a piano.

The **semi-circular canals** spring from the upper and back part of the vestibule. They are three in number placed in different planes, at right angles to each other, and communicate with the vestibule by five openings, as two of them unite before opening into the vestibule. At one end of each canal is a swollen portion, to the interior of which fibres of a branch of the auditory nerve are distributed. The semi-circular canals are concerned with keeping the equilibrium of the body and make us aware of our position and movements in different directions. The fibres of the



Fig. 91.—A bony Labyrinth removed from the temporal bone in which it lies.

(From Quain's 'Anatomy.'
By permission.)

(2½ times the natural size).

- 1, vestibule ; 2, oval window ;
3, 4, 5, semi-circular canals ;
6, 7, 8, the cochlea ; 9, round window.

¹ Organ is here used in the sense of a musical instrument.

auditory nerve arising from the semi-circular canals do not go to the auditory centre of the brain but have been traced to the cerebellum which is concerned with the balancing of the body. Disease of the cerebellum or the semi-circular canals gives rise to dizziness.

Transmission of waves of sound to the end-organ of hearing.—Every body making a sound is vibrating and imparting these vibrations to the air, causing waves to be propagated in all directions. These sound waves travel in the air at

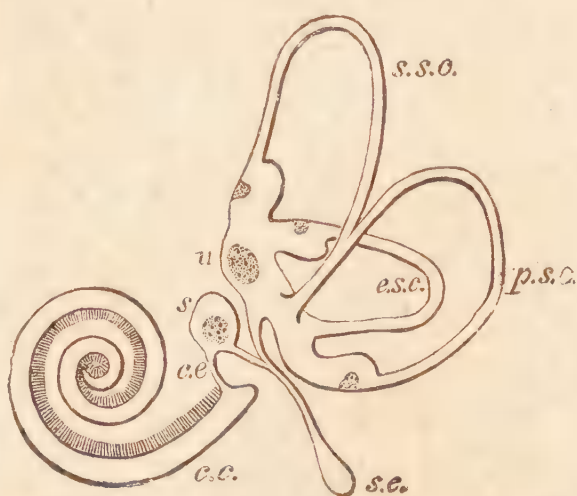


Fig. 92.—A membranous Labyrinth removed out of a bony Labyrinth.

(From Quain's 'Anatomy.'
By permission.)

u, s, and s.e., parts of the vestibule; *s.s.c., p.s.c., and e.s.c.,* the three semi-circular canals; *c.e.,* uniting canal; *c.c.,* cochlea. The shaded areas indicate the parts to which branches of the auditory nerve are distributed.

of the auditory nerve in the organ of Corti and produce a nervous impulse which on reaching the brain gives the sensation of sound.

Deafness.—It is obvious that deafness may be due to various causes. It may be due to blocking of the auditory canal by ear-wax, or the rupture of the drum by anything pushed into it, or as the result of disease of the middle ear. Occasionally blocking of the Eustachian tube from inflammation in the throat produces defect in hearing. Lastly disease of the inner ear, auditory nerve, or the hearing centre in the brain may give rise to it.

the rate of 1,100 feet per second, and reaching the external ear pass through the auditory canal and strike against the tympanic membrane thus setting it into vibrations. These vibrations are transmitted to the malleus which is attached to the inner side of the drum, and this sets the incus and the stapes into corresponding vibrations. The foot-plate of the stapes being inserted into the oval window, produces vibrations in the perilymph which are communicated to the endolymph contained inside the membranous labyrinth. These vibrations of the fluid then excite the terminations

CHAPTER XXI

THE LARYNX AND VOICE

The Larynx.—The Larynx or the organ of voice, is the upper modified portion of the trachea. Its walls consist mainly of cartilages bound together by muscles and ligaments. The interior of the organ is lined by mucous membrane

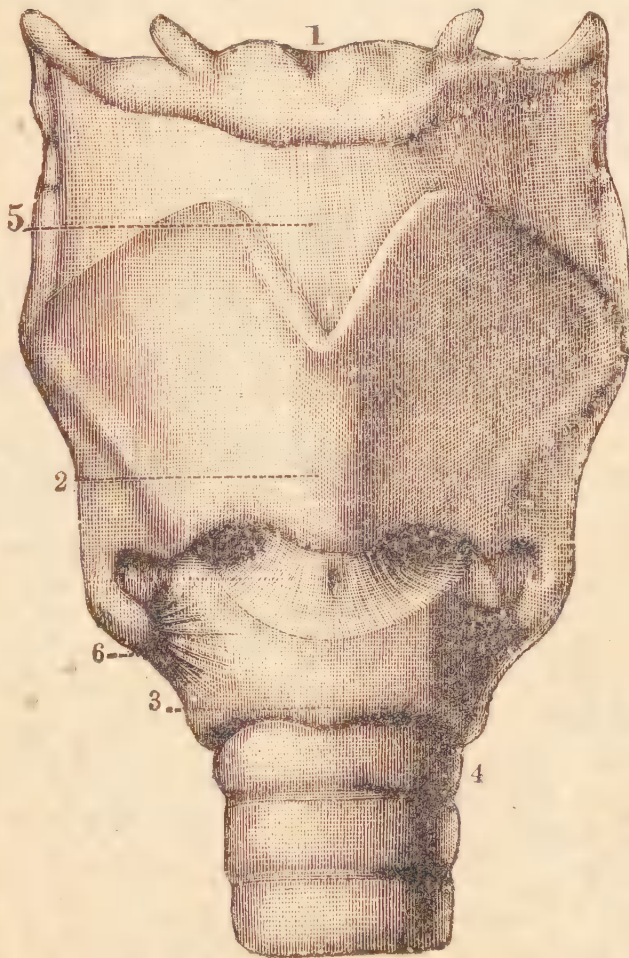


Fig. 93.—Front view of the Larynx.

(From Quain's 'Anatomy.' By permission.)

1, hyoid bone ; 2, thyroid cartilage ; 3, cricoid ; 4, first cartilaginous ring of the trachea ; 5, membrane ; 6, ligaments.

continuous with that of the mouth above and of the trachea below.

The cartilages forming the larynx are four in number, the thyroid, the cricoid, and the two arytenoid cartilages.

The epiglottis and the hyoid bone though not strictly speaking included in the larynx, are closely associated with it and may conveniently be described here.

The **thyroid** forms the greater part of the front and sides of the larynx, the prominent ridge of which is popularly known as Adam's apple. It is incomplete behind, the space between the two wings being filled up by a membrane. Above it is connected with the hyoid bone by a membrane and below it articulates on each side with the cricoid cartilage.

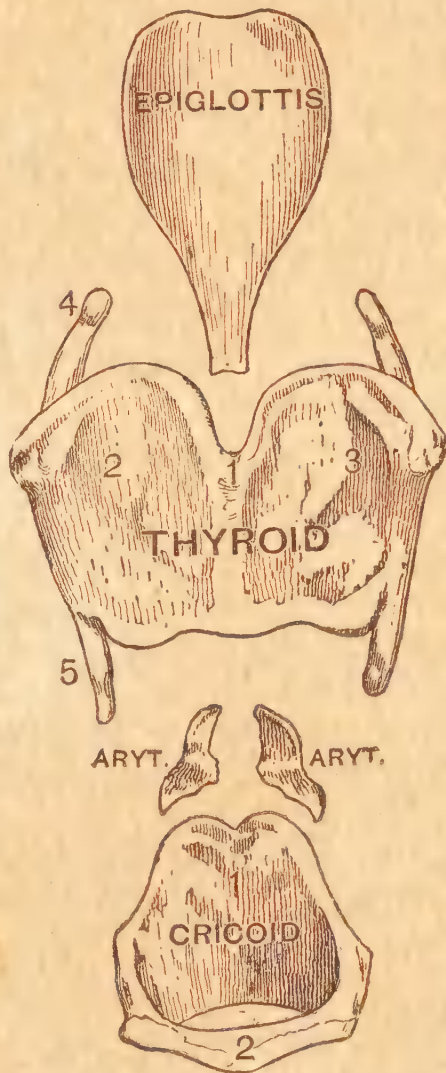


Fig. 94.—Cartilages of Larynx, separated and seen from before.

(From Thornton's *Elementary Practical Physiology*. By permission.)

The **cricoid** cartilage lies below the thyroid and is the only complete ring in the windpipe. It is shaped like a signet ring, the broad part of which lies behind, while the front part is narrow. The space between it and the thyroid is filled by a membrane. On the upper part of the broad portion behind rest, on either side, the arytenoid cartilages.

The **arytenoids** are two small pyramid-shaped cartilages lying one on either side, on the top of the posterior broad portion of the cricoid cartilage, and forming movable joints with it. Stretching between the arytenoid cartilages and the back surface of the thyroid cartilage are two elastic fibrous bands covered over by mucous membrane. These are the **vocal cords**. They are attached close together so that when they

are stretched, their edges are brought nearly parallel and only a small chink is left for the air to pass through. Above the vocal cords, are two other folds of tissue situated one on each side, called the false vocal cords, which take no part in the production of voice.

The **epiglottis** is a leaf-like piece of cartilage, the lower

and narrower part of which is attached to the thyroid cartilage. It acts as a lid closing the larynx during the act of swallowing, thus preventing food and drink from getting into the trachea. During ordinary respiration the epiglottis remains erect.

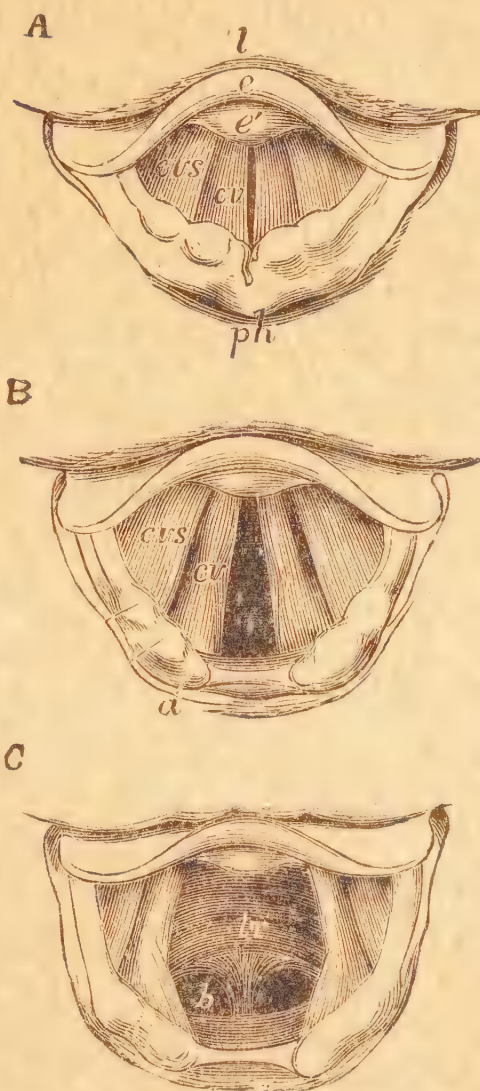


Fig. 95.—Three views of the larynx during life.
(From Quain's 'Anatomy.' By permission.)

As seen by looking down the throat by the aid of the instrument called laryngoscope. A, during the singing of a high note; B, during quiet breathing; C, while taking a very deep breath.

cv, vocal cords; *cvs*, false vocal cords; *tr*, front wall of the trachea, *b*, commencement of the two bronchii, as seen through the wide passage.

The **hyoid** bone is a small U-shaped bone lying above the thyroid cartilage at the base of the tongue, with its convexity directed forwards. It does not articulate with any other bone but is suspended by ligaments from the

base of the skull. The bone gives attachment to many of the muscles of the tongue and the larynx.

Voice and Speech.—As already stated, sound is produced by regular movements of vibrating bodies. Voice is the sound produced by the vibrations of the vocal cords. During ordinary breathing vocal cords are relaxed, the opening of the glottis is wide and the air can pass through it freely (Fig. 95, B). When we speak or sing the vocal cords are tightened by means of the muscles attached to the cartilages and the glottis is narrowed into a cink (Fig. 95, A). The outrushing blast of air thus sets the cords into vibration producing sound.

The pitch of the note depends upon the number of vibrations per minute and these depend upon the tension and length of the cord. The greater the tension or shorter the cord the higher is the pitch of the sound produced because the number of vibrations per minute are increased. This can be illustrated by means of a wire or string stretched between the points as in a *sitar*.

The quality of the voice depends upon various conditions such as the shape of the mouth, nose and pharynx, the position of the tongue, etc., and is peculiar to each individual. The larynx is exactly alike in boys and girls, but on reaching the age of youth, the larynx of the male rapidly increases in size causing a corresponding increase in the length of the vocal cords and consequent change in the pitch of the voice.

Speech is voice broken up into words by movements of the tongue against the cheeks, lips and teeth. Whispering is speech without sound as there is no movement of the vocal cords. In it the air current is simply moulded into speech by movements of the tongue and lips.

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